

DEFINITIONS OF TERMS USED IN TABLE

- A. Whiteness Has no reference to hiding power, but to appearance only. Some pigments are very white, but are without opacity, that is, transparent in oil, such as Silica, Terra Alba, etc.
- B. Spreading The extent to which paint may be brushed out over a surface. Thus we say a paint made with Zinc Oxide has great spreading, while a paint made with Basic Carbonate-White Lead is deficient in spreading.
- C. Stable (or inert.) A "stable material" is one that neither undergoes nor causes chemical change when mixed with other ingredients. Zinc Oxide and Basic Sulphate-White Lead are stable or inert, while Basic Carbonate-White Lead is unstable as it destroys Linseed Oil (with which it forms a Lead Soap which will lead to chalking) unless proper reinforcing pigments are added to retard this chemical action. Likewise certain blue, red and green colors are damaged and even destroyed if mixed into paint with Basic Carbonate-White Lead.

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D. Opacity
or Hiding.
(covering)

Means hiding power in a paint, that is, the quality of concealing the surface underneath. Not the same as body, as a paint may be very heavy bodied and yet not cover up or hide properly.

E. Tooth

A necessary quality in pigments, which prevents paint from "slicking" or brushing out too thin. Good tooth means proper "feel or drag" under the brush. Where Basic Carbonate-White Lead should not be used because of its destructive action on the color and where Basic Sulphate-White Lead is used, "tooth" must be given, and may be obtained by adding small quantities of the proper reinforcing pigments.

F. Anti-
Settlers and
Non-Settling.

Many pigments settle down out of the paint to the bottom of the package. Magnesium Silicate (Asbestine) and Aluminum Silicate are "Anti-Settlers" as they only do not sink but act as a web to hold up the heavier pigments.

Blanc Fixe is a non-settler.

G. Gas-proof

Pigments which are gas-proof, (for example Zinc Oxide, Basic Sulphate-White Lead, Silica etc.) are not changed in color or texture by the gases or vapors present in the air. Basic Carbonate-White Lead and Carbonate-White Lead blacken under exposure to coal gas and perish under exposure to certain other gases, such as kitchen and barn vapors.

H. Paint-Coat Strengtheners.

Three coats of properly made paint are only about 3/1000 of an inch thick. To weave the pigment particles together into a strong film, Aluminum Silicate and Magnesium Silicate are needed, because no matter how finely ground, they always remain in the shape of rods or flakes, and they thus strengthen the paint coating as rods or webs of steel in concrete, hair in plaster, and wire mesh in modern woven wire glass.

Density

or

Impenetrability

A vital quality secured by using pigments of at least three sizes. If a single pigment is used, all the particles are of an average size, and too great a quantity of the vehicle, that is the oil, is exposed to surface wear and to decay from the air. Just as concrete needs, (a) comparatively coarse broken rock (b) fine rock or gravel, and (c) sand, so good paint should contain (a) coarse pigment like Basic Carbonate-White Lead or Sulphate of Barium (b) medium sized pigment, like Calcium Carbonate or Blanc Fixe (including the Paint-Coat Strengtheners and Anti-Settlers), and (c) exceedingly fine pigments, like Zinc Oxide and Basic Sulphate-White Lead. Such a combination is dense and exposes less of the oil and more of the pigment (which is the indestructable part of the paint) to the action of the air.



Consulting Board:

CHARLES B. DUDLEY, Ph.D.

Chemist
Pennsylvania Railroad
Altoona, Pa.

ALLERTON S. GUSHMAN, Ph.D.

Assistant Director
Office of Public Roads
Agricultural Dept.
Washington

S. S. VOORHEES

Engineer of Tests
Office of Supervising Architect
Treasury Dept.
Washington

BUREAU of PROMOTION and DEVELOPMENT

Paint Manufacturers' Association of United States

SCIENTIFIC SECTION—ROBERT S. PERRY, Director

3500 Grays Ferry Road, Philadelphia

Gentlemen:—

Attached you will find copy of "PIGMENT NOMENCLATURE TABLE" prepared for the use of the manufacturers by the Scientific Section, and officially endorsed by the Legislative Committee of the Paint Manufacturers' Association. It contains the gist of "A Paint Catechism for Paint Men — by Geo. B. Heckel" in a condensed form.

It is the hope of the Scientific Section that this Table will prove of value to the manufacturer.

Very truly yours,

R. S. PERRY

Director of Scientific Section.

P. S. The Scientific Section will soon issue a table containing the Standard Nomenclature and Physical Characteristics of the different colors.

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REPORTS OF THE

BUREAU OF PROMOTION AND DEVELOPMENT
PAINT MANUFACTURERS' ASSOCIATION OF UNITED STATES
SCIENTIFIC SECTION—ROBERT S. PERRY, DIRECTOR
 3500 GRAYS FERRY ROAD, PHILADELPHIA

WHITE PIGMENTS—STANDARD NOMENCLATURE—PHYSICAL CHARACTERISTICS

PIGMENT. ALLOWABLE NAMES	OPTIONAL BRACKET WHEN OF THE PARTICULAR GRADE	QUALITIES	DEFECTS NEEDING CORRECTION OR REINFORCING
Zinc Oxide	(Horsehead) (Western) (Mineral Point) Etc., Etc.	Extremely white. Great spread- er. Stable. Non - chalking. Great fineness. Carries much oil. Good opacity.	Requires blending (to offset tendency to peel and for both density and thick- ening of coat) with coarser pigments, for example, Calcium Carbonate. Lacks tooth.
Basic Carbonate—White Lead or (Corroded White Lead)		Fairly white. Very opaque. Good tooth.	Settles very badly unless reinforced. Not stable. Alkaline and damages many colors. Chalks. Coarse. Black- ened by coal gas. Damaged by other gases and vapors. Poor spreader. Should be corrected by addition of suitable reinforcing pigments.
Carbonate White Lead or Precipitated Carbonate—White Lead	(Precipitated)	Uniform fineness. Non-settler compared with corroded lead. Opaque. Good tooth. White.	Like corroded lead, requires correction for chemical action. Should be cor- rected for spreading qualities with Zinc Oxide or other pigment.
Basic Sulphate—White Lead or Basic Sulphate—Sublimed Lead	(Sublimed)	White. Stable. Great spreader and very opaque. Very resistant to coal gas and other gases. Great fineness.	Requires blending with coarser pig- ments to improve tooth or brushing qualities.

Print Manufacturers' Association, United States

MEMBER OF THE INTERNATIONAL ASSOCIATION OF PRINTERS

CONSTITUTED IN 1882

INCORPORATED IN THE DISTRICT OF COLUMBIA

OFFICE: 1000 K STREET, N.W., WASHINGTON, D.C. 20004
TELEPHONE: (202) 462-1234
FAX: (202) 462-1235
E-MAIL: info@printers.org
WEBSITE: www.printers.org
The Print Manufacturers' Association is a non-profit organization dedicated to the promotion and protection of the interests of the printing industry in the United States. It is a member of the International Association of Printers (IAP) and the United States Printing Industry Council (USPIC).

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PIGMENT. ALLOWABLE NAMES	OPTIONAL BRACKET WHEN OF THE PARTICULAR GRADE	QUALITIES	DEFECTS NEEDING CORRECTION OR REINFORCING
Zinc Lead White		A sublimed product. Exclusively used to describe a product containing approximately : \ Zinc Lead, 50% / Lead Sulphate, 50% Opaque. Non-settler. Stable.	Lacks complete whiteness. Lacks tooth and has defects like Zinc Oxide. Requires correction or treatment with reinforcing pigments.
Lithopone	(Green Seal Beckton) (Gold Seal Beckton) Etc., Etc.	Good body. Very opaque. Non-settler. Fair tooth. Good spreader. A precipitated double compound of Zinc Sulphide and Barium Sulphate. Exclusively used to describe a product containing not exceeding 70.6% Barium Sulphate.	With excess of Basic Carbonate-White Lead it darkens. Liable to fog in sun rays.
Barium Sulphate or Barytes	(Barytes)	Very stable. Good brushing qualities or tooth. Indispensable base for many colors. Retards chalking. Excellent corrective for excessive spreading.	When used in excess cheapens and adulterates. Lacks opacity. Requires blending with some anti-settler, for example Asbestine.
Precipitated Barium Sulphate or Barium Sulphate	(Blanc Fixe)	Very White and stable. Retards chalking of Carbonate-White Lead. Fair tooth. Good spreader. Non-settler. Great fineness. Important base in many colors.	Excessive use reduces hiding power.

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PIGMENT. ALLOWABLE NAMES	OPTIONAL BRACKET WHEN OF THE PARTICULAR GRADE	QUALITIES	DEFECTS NEEDING CORRECTION OR REINFORCING
Aluminum Silicate	(China Clay)	Anti-settler. Good spreader. Stable. Retards chalking. Good as a base for certain colors.	When used in <i>excess</i> cheapens and adulterates. Lacks tooth. Lacks opacity.
*Magnesium Silicate (Asbestine)	(Asbestine)	Magnesium Silicate (Asbestine) is an asbestos mineral notable for its fibrous structure and for holding up heavier pigments in paint. Indispensable anti-settler. Good coat strengthener. Good tooth. Stable. Retards chalking. Non-settler.	When used in <i>excess</i> cheapens and adulterates. Lacks opacity and [REDACTED] spreading.
*Magnesium Silicate (Talcose)	(Talcose)	Magnesium Silicate (Talcose) is a Talc mineral notable for its tabular structure and approximating the properties of China Clay. Stable. Retards chalking. Non-settler.	When used in <i>excess</i> cheapens and adulterates. Lacks opacity and [REDACTED] spreading.
Calcium Carbonate	(Whiting) (Paris White) (White Mineral Primer) (White Mineral Primer Crystalline)	Corrects free acidity. (Free acid) in linseed oil, and also in certain browns and reds (Oxides). Moderate opacity. Increases density of paint. Thickens coat. Non-settler.	
Hydrated Calcium Sulphate or Calcium Sulphate	[REDACTED] (Terra Alba)	Stable. Good tooth. Indispensable part in some very valuable dry colors. Notably Venetian Reds.	When used in excess is an adulterant. Lacks opacity in oil.

*The Asbestine or Talcose varieties easily distinguished under magnifying glass.

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Dehydrated Calcium Sulphate or Dead burnt Calcium Sulphate		When dead burnt it becomes chemically inactive and is an important ingredient in some bright red oxides and other colors. Tone supporter.	
Partially Dehydrated Calcium Sulphate or Plaster Paris or Dental Plaster	(Calcined Gypsum)	Excellent for plaster and kalsomine.	Entirely unsuited for use in oil. Impairs quality because chemically active.
Silica or Sillex	(Quartz Silica) (Infusorial Earth) (Decomposed Silica)	Stable. Good filler. Excellent tooth.	Transparent in oil. When used in excess is an adulterant.

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VEHICLE—STANDARD NOMENCLATURE—PHYSICAL CHARACTERISTICS

VEHICLE. ALLOWABLE NAMES	OPTIONAL BRACKET WHEN OF THE PARTICULAR GRADE	QUALITIES	DEFECTS NEEDING CORRECTION OR REINFORCING
Benzine or Naphtha		So called when below 95° F. flash. The familiar volatile known as Naphtha or Painters' Spirits. On either paraffine or asphaltum base. Boiling point 120-150° F.	
Paraffine Spirits		So called when above 95° F. flash, and on a paraffine base. Evap- orative value about 25 minutes without leaving stain on paper. Penetrative value at least equal to Turpentine. Boiling point 150-210° F.	
Asphaltum Spirits		So called when above 95° F. flash, and on an asphaltum base. Fully adequate solvent properties for oil paints. Unlike benzine, these spirits possess fine flowing qual- ities and good flattening qualities. Better solvent for hard gums. Oxygen carrying qualities.	

*Both Paraffine and Asphaltum Spirits could be described as Petroleum Spirits if there be no desire or need to distinguish between these two materials.

R. S. PERRY,
Director

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<p style="text-align: center;">WATER</p> <p>Practice (allowed by State authorities) is to disregard presence of water in paint up to 1.5 % of the fluid portion, this amount being recognized as accidental or incidental to the raw materials or to the process of manufacture. All water beyond 1.5 % in the fluid portion to be stated on label.</p>		<p>A reasonably small percentage of water improves the non-settling conditions and improves the brushing qualities, also tends to satisfy the chemical activity of non-stable pigments, such as corroded lead, during process of manufacture, thus decreasing chemical activity of the applied paint, and promoting durability of the job.</p>	<p>More than a slight percentage of water means an emulsified paint, and when used in such excess is a cheapener and adulterant.</p>

NOTE.—At a later date this table will be supplemented by a complete vehicle chart.

R. S. PERRY,
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Density or Impenetrability.

A vital quality secured by using pigments of at least three sizes. If a single pigment is used, all the particles are of an average size, and too great a quantity of the vehicle, that is the oil, is exposed to surface wear and to decay from the air. Just as concrete needs, (a) comparatively coarse broken rock (b) fine rock or gravel, and (c) sand; so good paint should contain (a) coarse pigment like Basic Carbonate-White Lead or Sulphate of Barium (b) medium sized pigment, like Calcium Carbonate or Blanc Fixe (including the Paint-Coat Strengtheners and Anti-Settlers), and (c) exceedingly fine pigments, like Zinc Oxide and Basic Sulphate-White Lead. Such a combination is dense and exposes less of the oil and more of the pigment, (which is the indestructable part of the paint) to the action of the air.



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To the Paint Manufacturers' Association

MAY 8th, 1908.

The Scientific Section wishes to call your attention to some work which has been undertaken in its laboratories of late, and to ask your aid in joining with the Section in an endeavor to correct the evil of short measure in the paint industry.

Short measure has been a prevailing condition in the past, but in the future it will be an uncommon occurrence. The responsibility in many instances for this serious evil rests primarily with the can manufacturer. Previous to the reform movement, the manufacturer of commodities ordered his cans in the different capacities with the natural supposition on his part that he would get full sized packages, and, like the general public, remained in blissful ignorance of what he was buying. For this reason the manufacturer who received short weight cans was not dishonest in sending out these cans containing his own product, because he had no direct intention to deceive and was simply following in the footsteps of other manufacturers. A sagacious contract made by a manufacturer with a can company for a quantity of cans may have led the can manufacturer, either because of a rise in the price of raw material or because of a desire to increase his profits, to decrease the size of the package, and this explains the retrogression of the gallon can to some of the small sizes that have been examined in our laboratory.

The can industry has suffered in the past by the segregation of the different factories, the lack of some common work to

bring them in closer touch, and by the chaotic conditions which have prevailed. They have, however, been aroused to the broadening influence of the new era, and have been most eager to aid in such sweeping reforms as this section is promoting.

A large number of cans used by different manufacturers of paint in a certain Eastern city was sent to the Scientific Section, and investigation showed an average of 8% shortage in volume when the proper air space was allowed for, and even had the cans been filled to the top the shortage would have been 4%. Such an astounding shortage strongly impresses the Section that these conditions should at once be corrected. It has been found that the different style cans commonly used throughout this country have an average shortage of 7%, and the Section was very much surprised to find that some manufacturers of paint put out cans containing a shortage of as high as 15%. It is pleasing, however, to note that the reform movement, although a recent one, is constantly growing and enlarging, and the willingness with which the manufacturer in many cases sanctions the adoption of these standards goes to show the great interest that is being taken in this work.

We have secured hundreds of samples of cans from different can manufacturers throughout the country, and we have calibrated these cans and placed upon our files an immense amount of data on this subject. As a result of this work, we have decided on a series of cans in the proper sizes, and herewith recommend this list to the Association for universal use. The cans indicated in this list are of such a size that they will contain full United States measure, and, at the same time, have the necessary air space after the proper volume of liquid has been placed in the can. In order to arrive at conclusions regarding the proper air space necessary in cans, different sizes containing paint were obtained from several cities, and upon investigation it was found that 75% of the manufacturers favored one-half inch air space for gallon and one-half gallon cans, and three-eighths inch for one-fourth gallon and one-eighth gallon cans.

The several can manufacturers have given us valuable aid in our work, and they seem desirous of falling in line with the Association to aid in promoting the use of these standard size packages. This movement will simplify the number of dies used, reduce the amount of stock to be carried and in other ways prove a benefit to the can manufacturer as well as to the consumer, and ultimately work toward the lessening of the cost of manufacture, with an attendant decrease in price.

Please give this matter your attention, and do not hesitate to correspond with this Section, if we can furnish you with any further information on the subject.

R. S. PERRY,
Director Scientific Section.

Can Sizes Recommended to the Paint Manufacturers' Association by the Scientific Section

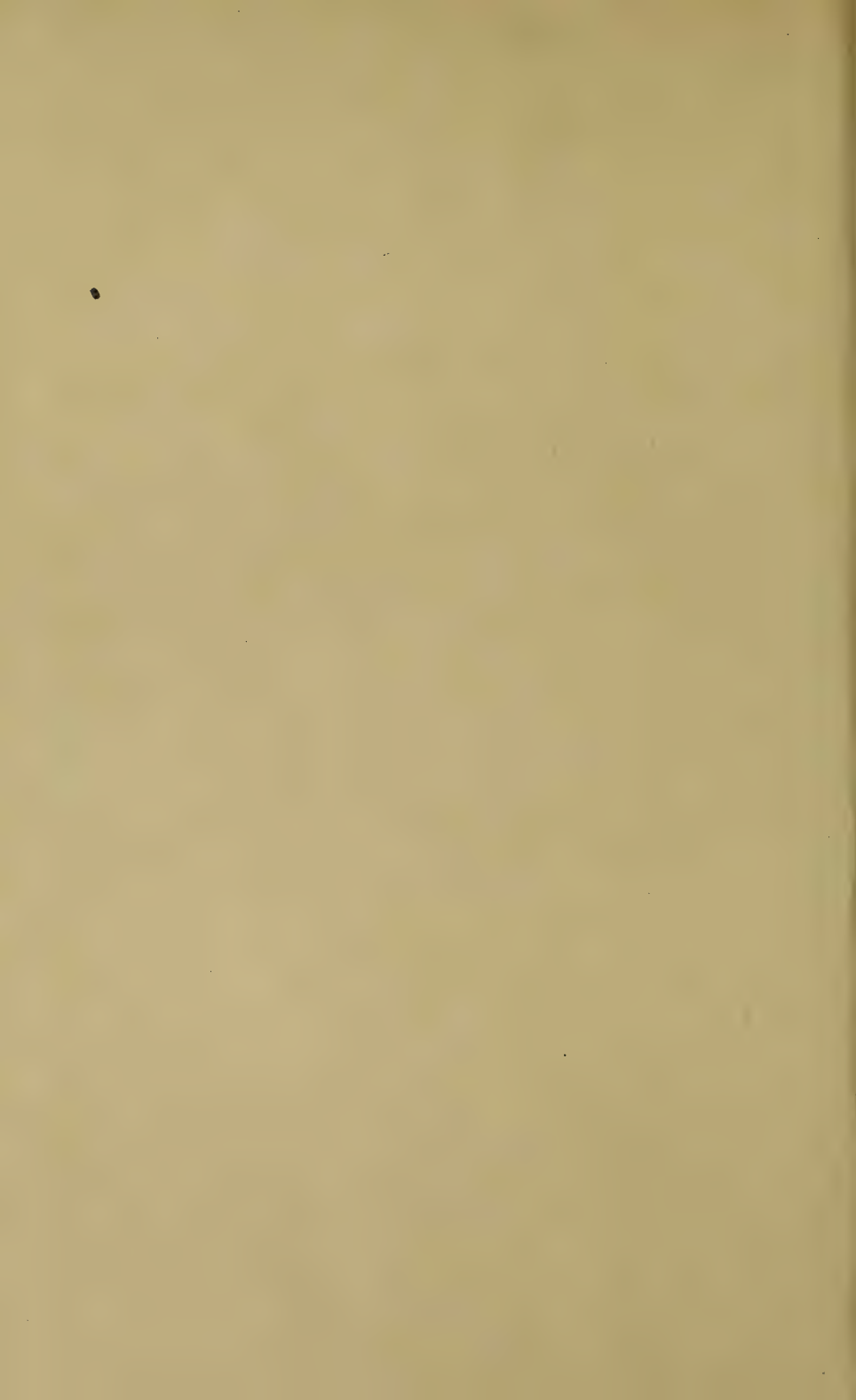
(In some cases, optional sizes are given holding the same volume.)

Hole and Cap	Friction Top	Open Top or Double Seam
Gallon { $6\frac{5}{8} \times 7\frac{1}{2}$	$6\frac{3}{4} \times 7\frac{1}{2}$ $6\frac{5}{8} \times 7\frac{3}{4}$	$6\frac{3}{4} \times 7\frac{1}{4}$ $6\frac{1}{2} \times 7\frac{5}{8}$ $6\frac{5}{8} \times 7\frac{1}{2}$
$\frac{1}{2}$ Gal. { $5\frac{3}{8} \times 5\frac{7}{8}$	$5\frac{5}{16} \times 6$ $5\frac{1}{4} \times 6$	$5\frac{3}{8} \times 5\frac{3}{4}$ $5\frac{1}{8} \times 6\frac{7}{16}$
$\frac{1}{4}$ Gal. { $4\frac{1}{4} \times 4\frac{3}{4}$ $4\frac{3}{16} \times 4\frac{7}{8}$	$4\frac{1}{4} \times 4\frac{7}{8}$ $4\frac{3}{16} \times 5\frac{1}{8}$	$4\frac{3}{16} \times 4\frac{7}{8}$ $4\frac{3}{8} \times 4\frac{5}{8}$
$\frac{1}{8}$ Gal. { $3\frac{1}{2} \times 3\frac{5}{8}$ $3\frac{3}{8} \times 3\frac{3}{4}$	$3\frac{1}{2} \times 3\frac{3}{4}$ $3\frac{3}{8} \times 3\frac{7}{8}$	$3\frac{3}{8} \times 3\frac{3}{4}$
Roll Seam		Palmer Star
Gallon { $6\frac{5}{8} \times 7\frac{1}{2}$ when open $6\frac{5}{8} \times 7\frac{5}{16}$ when closed		$6\frac{1}{2} \times 7\frac{3}{4}$
$\frac{1}{2}$ Gal. { $5\frac{3}{8} \times 5\frac{13}{16}$ when open $5\frac{3}{8} \times 5\frac{5}{8}$ when closed		$5\frac{1}{4} \times 6\frac{1}{8}$
$\frac{1}{4}$ Gal. { $4\frac{1}{4} \times 4\frac{3}{4}$ when open $4\frac{1}{4} \times 4\frac{9}{16}$ when closed		$4\frac{3}{8} \times 4\frac{7}{8}$ $4\frac{1}{4} \times 5$
$\frac{1}{8}$ Gal. { $3\frac{3}{8} \times 3\frac{7}{8}$ when open $3\frac{3}{8} \times 3\frac{11}{16}$ when closed		$3\frac{1}{2} \times 3\frac{3}{4}$ $3\frac{3}{8} \times 3\frac{7}{8}$

NOTE.—The gallon and half gallon cans hold full volume to within $\frac{1}{2}$ inch of top, and the quarter gallon and eighth gallon cans to within $\frac{3}{8}$ inch of top.

FIRST REPORT *on the*
TEST FENCES *Erected*
by the SCIENTIFIC SECTION

Paint Manufacturers'
Association
of the United States



107053

There is a desire among certain manufacturers to raise the standard of excellence in the paint trade and give their best efforts to wipe out misunderstandings and prejudices, upon the part of the public, regarding the usefulness of many important new materials used in the manufacture of paints.

This brings us face to face with the fact that it is necessary that practical tests should be made—made not only by practical men, but made along scientific lines in order to arrive at definite conclusions.

The advisability of such tests is apparent at the out-start, and many who are interested in the honest paint legislation, which is at present occupying the attention of the whole industry, express regret that these tests had not been made ten years ago, so that definite and indisputable evidence might be at hand to demonstrate to misinformed lawmakers the unfairness of restricting manufacturers of paints to a certain few so-called statutory pigments which have been instilled into the minds of these legislators, as the only proper ones that should be used. If these pigments in different combinations prove their value over all other combinations, well and good; but if we find that other pigments may be incorporated up to a certain extent, and find out the approximate limit of the use of these reinforcing pigments in improving the paint, then we will have gone a step higher in the production of a superior product. Authorities on paint differ as to the value of some pigments and their proper percentage in the composition of paints, but all agree that the BEST PAINT is yet to be produced. It would be idle for anyone to claim that a certain combination of pigments produces the best and only honest paint, and then lay back satisfied that no further progress can be made and endeavor to smother the ambition of the investigator who is trying to advance the industry with his scientific or practical researches and studies.

Object of
Tests

Statutory
Pigments

Use of Reinforcing Pigments Scientific investigation has shown that reinforcing materials lend certain qualities to paint, but these materials should be used with scientific precision, understanding, and in moderation. The public is becoming more and more discriminating and the progressive and the reputable manufacturer does not indulge in addition of reinforcing pigments to his paint before he has found out the proportions in which such pigments become beneficial.

Value and qualities of Pigments The percentages of the so-called reinforcing pigments, such as silica, blanc fixe, aluminum silicate, magnesium silicate, calcium carbonate, calcium sulphate, etc., which benefit a paint, if they do benefit, and just how they serve their intended purpose is a question which we hope these tests will show. Certain of the many paints placed upon these fences contain these inert pigments in varying percentages, so that conclusions may be drawn showing the safe limit of these various pigments, beyond which the manufacturer must not go in the compounding of paints. To show the proper value, not only of these reinforcing pigments, but of the various white base pigments, such as zinc oxide, basic carbonate white lead, basic sulphate white lead, zinc lead white, lithopone, etc., will guide the manufacturer in producing, and the public in choosing, paints, having that trinity of requirements, namely, hiding power, covering and spreading power, and the maximum durability—those qualities which the master painter looks upon as essential. When these different formulæ have been tried out and the work has demonstrated the value of the different pigments, then the manufacturer believes he will have certain data which will justify the honest products of the day and will condemn the dope. The master painter will have these tests to aid his judgment in choosing between the various formulæ, and the architect will have at hand for his inspection results of which he may take advantage in gaining knowledge upon which to base his future specifications.

Result of Tests

The question of vehicle is as important as that of pigment, and demands honest products and proper treatment. The painter wishes to secure a paint which, when dry, will be improved by the composite characteristics of the contained pigments, and which will be strengthened by these different pigments to a high point of elasticity and strength, or of such an elasticity that there is no undue strain on the surface upon which it is used and which will, at the same time, have excellent sealing properties, excluding gases and vapors of the air which would tend in some cases to alter the pigments. He requires a paint that will brush and spread properly, and one which he can reduce in accordance with the nature of the wood to which he is applying the paint in order to satisfy the absorbing properties of the wood and properly bind the pigments to the surface.

Vehicle
Characteristics

The paints used in the test have been applied in white, yellow and gray, the latter two colors having the same percentage composition as the white, with the exception of the small per cent. of tinting base used.

Colors

The various colors, such as reds, blues and greens, have been tried out as special tests upon panels primed with different white base pigments in order to determine what base to use for certain of these colors which in the past have given the painter much difficulty after they have been applied, some fading, some darkening, and others showing very peculiar and troublesome results.

Permanency
of Colors

The climatic conditions, peculiar to the places where these fences have been erected; Atlantic City, where the salt air has an accelerated destructive effect upon paint, and Pittsburg, where the coal and sulphur gases act with remarkable force; will serve to give in a short period,

Climatic
Conditions



Atlantic City Test Fence

some idea of the wearing quality of the different combinations.

Owing to the lateness of the season and inclemency of the weather when this work was started, it was deemed inadvisable to place the panels upon the fences and do the painting outside. This would have caused difficulty in drying and the painting of the different panels would have been subject to unequal conditions of application. Furthermore, the property of paint, when very cold, is to thicken and gelatinize or, expressing this in the vernacular of the painter, "to liver," and in order that we might be assured that the paints were being applied under fair and average conditions, it was deemed advisable that the painting should be done indoors under conditions of temperature and conditions of the atmosphere as would make our tests normal and valuable. A further advantage lies in the fact that the early part of the year is a season comparatively free from dust, and consequently when our panels were screwed on the fence there was absence of this unfavorable feature. For this reason a building was rented within close proximity to the Atlantic City fence and previous to the painting, was used for the storage of the panels and the paints. In this building were placed proper scales and measures necessary for the tests. All the paint was carefully looked after, and no one allowed in the building without proper authority.

The painting of the panels was done in this building by a painter selected by the Master Painters' Association of Pennsylvania, in the presence of the inspector of the fence. When the panels were finished they were removed and placed in their proper position on the fence.

Committee E, of the American Society for Testing Materials, was directly in charge of these tests, and the chairman of this committee, Mr. Job, had his inspector on the ground throughout the work.

The Philadelphia Branch of the Master Painters' Association appointed Mr. Butler as official painter of the

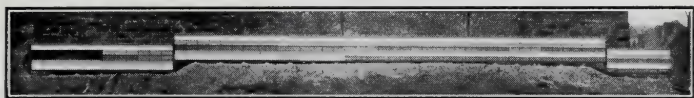
Object of Inside
Application

Committee "E"

fence, and Mr. Butler's painter and inspector was present with Mr. Campbell, the inspector from the Paint Manufacturers' Association throughout the work.

At Pittsburg, where the fence was under the supervision of the Carnegie Technical Schools, Prof. James, chairman of the Fence Committee, was represented by a man in similar capacity of weigher and inspector. At

Pittsburg Fence
Committee



Pittsburg Test Fence

Pittsburg the local branch of the Master Painters' Association also appointed an official painter, Mr. A. C. Rapp, whose inspector was present throughout the work. This work was also done under the supervision of Mr. J. B. Campbell, inspector for the Scientific Section of the Paint Manufacturers' Association.

Mr. Henry A. Gardner, chemist to the Scientific Section and supervisor of the test fences, herewith presents his report on the construction and arrangement of the tests. Supplementary reports of the inspectors follow.

R. S. PERRY, *Director.*

*Scientific Section, Paint Manufacturers' Association,
Phila., Pa.*

Mr. R. S. Perry, Director,
Scientific Section,
Paint Manufacturers' Association of the U. S.

DEAR SIR:—The following is a report on the construction and arrangement of the Atlantic City and Pittsburg Test fences:

LOCATION OF FENCES.

Site
Atlantic City

At Ventnor, three miles below Atlantic City, on the Atlantic Coast, a site was selected for the erection of the first fence. The site is 200 feet long and 10 feet wide, running North and South within the following boundaries: Between Mobile, Arctic, Atlantic and Savannah avenues, and within 100 yards of the salt water. This fence runs North and South, giving East and West exposure.



Another View of Atlantic City Test Fence

Pittsburg

The site for the Pittsburg fence is at Carnegie Institute. The fence is located upon a high bluff overlooking the ravine, opposite the Women's Building, and this fence runs East and West, giving a Southern and Northern exposure, the Northern exposure being subjected to smoke and fumes wafted up from various smelting works. Because of the high ground upon which this fence is placed, this exposure test will be most excellent.

CLASSIFICATION OF LUMBER.

Inspection

The lumber used in the construction of the panels for these fences was selected with exceptional care. First,

a large amount of this lumber was secured after it had been kiln dried for ninety days at an even temperature,



Cypress Panels

and subsequently weathered for ninety days in the lumber yard. A large amount of this lumber was then selected by an expert lumber classer and sent to the carpenter with specifications for the panels. After the carpenter had finished near 1,600 of these panels in the various woods used, namely, white pine, yellow pine and cypress, the expert lumber classer was again engaged to look these panels over thoroughly and to discard and reject any panel which he thought it would be unfair to use for a test of this nature, so that in the application of any formula to the panel it could not be claimed that the formula was injured by the condition of the wood of the panel selected. Out of the 1,600 panels, 1,200 panels were selected for the two fences and forwarded to their proper destination.

Moisture exists in wood in two conditions: within the substance of the cell walls and in the pores, or lumina, of the cells. The strength of lumber is indirectly proportional to the amount of moisture in the cell walls, and after these walls have been satisfied and have reached the fibre saturation point, addition of free water to the pores of the wood has no weakening influence.

Strength of
Panels

The lumber selected for the panels having been brought back to the weathered condition after the kiln drying, naturally had opportunity to assume its fibre saturation point to the degree that weathering would promote this point, and being made into panels at this period, added moisture or moisture encountered under exposure after painting would not tend to cause swelling, warping or lessening of the strength of these panels.

BRANDING.

The panels were all branded with a hot iron, consecutively from No. 1 up, and the different kinds of wood were noted by an abbreviated brand mark, W standing for white pine, Y for yellow pine, and C for cypress.



White Pine Panels

PHOTOGRAPHING OF PANELS.

These panels were placed in frames after they had been built and passed by the lumber expert. The camera was set upon a platform at a certain distance from the panels. The camera being then set up and accurately focused, the time and light conditions were noted, and from experiments it was found that an exposure of one second with a clear bright sky gave good results, the negatives showing wonderful detail. Every panel was photographed, and after making a print of the negative, these prints were placed in an album so that at any time the condition of any panel upon either fence may be noted by referring to the number of the panel and looking it up in the album, which will give a detailed photograph of the panel in question.

CONSTRUCTION OF FENCES.

Twenty-nine heavy yellow posts squared to 6 in. were set in the ground, 6 ft. 4 in. apart, to the depth of 4 ft., upon a concrete base. The dirt was solidly tamped around the posts and cement was used within six or eight inches of the top of the ground and supplementary braces of 2 x 4 studding were used.

Studding of 6 in. x 2 in. was used, running from one post to another, both at the top and bottom of the fence, thus forming a solid frame work, the bottom of which is over 12 in. from the ground. The bottom, as well as the top of each fence, is protected by heavy timbers so as to keep the moisture from the ground penetrating the lumber.

Twelve-inch plain white pine sheathing was placed on both sides of the frame work, forming a solid background which was painted with Prince's Metallic Brown. Upon this background on both sides were placed the panels, firmly set in place with round-headed screws which may easily be removed and the panel transferred to the laboratory for microscopical or other tests at any time desired. The panels are three feet long, 15½ in. high, made

of German weather-boarding, three strips to a panel, firmly backed with braces, and nailed together in such a manner that no portion of the nails appear on the surface of same, thus preventing any staining of the wood from rust. Each panel is capped with a weather table running the full length of the panel and projecting 1 in.



Yellow Pine Panels

over same. Each section of the fence accommodates ten panels on either side, making a total of 560 panels, on each fence.

As nearly all the houses in this country are built of weather-boarding, we have selected same as being the most practical for the test. Ordinary weather-boarding is split diagonally from $\frac{3}{4}$ -inch lumber, and when placed together forms a very fragile panel. For this reason German weather-boarding was selected, same fitting closely together and forming a stout panel, and thus preventing any spaces for the admission of moisture.

Because of the exposure of the Atlantic City fence to the sweep of strong sea winds, it was decided to brace each post with an 18-inch length of 2 in. x 6 in. studding, nailed crosswise about 6 in. below the surface of the

ground. Also to run guy wires from every second post alternately on both sides of the fence to stakes in the ground about five feet from the fence.

ACTINIC LIGHT TESTS.

Recent investigations into the nature of light have proven that it is the ultra violet invisible rays that are most energetic in setting up chemical action. These rays are also called actinic rays. It is the actinic rays which affect the photographic plate and give rise to many chemical reactions—consequently it is very important to know the relation of actinic light to the breaking down of paint.

Small plates of clear window glass and small plates of orange colored glass, size $5 \times 2\frac{1}{4}$ inches, were placed



Atlantic City Fence Before Placing Panels

upon the middle weather-board of certain panels and held in place with tinters' tacks, and then a small amount of putty was placed around the edges to make the frames water-proof and so prevent the painted surface of the panel from being acted upon by the atmospheric changes.

At certain periods of time the glass slides will be removed from certain panels and observations made to determine whether the painted surface, protected from the actinic light rays by the orange colored glass, has suffered less than the painted surface not protected from actinic light rays by the ordinary white clear glass.

OPACITY.

In order that a test of the opacity of different paints to be applied to the fences may be made, a Maltese cross about four inches in height was stencilled upon each panel with lampblack and japan. As it would not have been fair to place the cross upon the wood before the first coat was applied, because of the difference in penetration of the vehicles and pigments used in the different kinds of paint, the cross on each panel was placed over the first coat.

The hiding power or opacity of the second and third coats of paint were observed after they had become dry.

Pigments in oil differ in their opacity in direct proportion to the difference between the refractive indices of the pigment and the refractive indices of the vehicles with which they are used. However, it is necessary that a paint should protect the underlying surface from the destructive action of the actinic rays of light, and with this idea in view the investigation of the different combinations and the effect of the actinic rays upon them, also the effect of the visual rays of light, are results which we hope to obtain with these tests.

H. A. GARDNER,
Engineering Chemist.

To Mr. R. S. Perry, Director,
Scientific Section,
Paint Manufacturers' Association of the U. S.

GENERAL REPORT OF PAINT TESTS MADE IN ATLANTIC CITY.

On January 16th, the work on the Atlantic City test fence was started. The weather was fairly clear and dry for that season of the year, and the temperature was 35° F. inside the house where the paint was applied. The work was all done in the presence of the official inspector and weigher, Mr. Parthree for Committee E, of the American Society for Testing Materials; Mr. Pablo, painter for Geo. Butler, who was appointed official painter of the fence by the Master Painters' Association of Philadelphia, and myself, and was under the direction of Mr. H. A. Gardner, of the Scientific section.

The panels were arranged in sets of six—first, two white pine; second, two yellow pine; and third, two cypress—by Mr. Parthree, and in their proper sequence with regard to the consecutive numbers branded on these panels.

PAINTS. The various paints were received in quart cans labeled "Paint Manufacturers' Association," and the number of the paint contained therein, but with no information regarding the name of the manufacturer who prepared the paint or other directions or information regarding reduction, etc. The various white leads used were received in kegs of 12½ lbs. each.

BRUSHES. A heavy 7-0 round bristle brush was used for the priming coat, so that the paint could be thoroughly worked into the wood. On the second and third coats a three-inch flat chisel brush was used. These

were washed and cleaned thoroughly in two washes of turpentine after applying one number of paint on all six panels in one color. The painter then worked out all the paint from the brush and set the brush in pot No. 1, turpentine. The inspector then washed them thoroughly in pots Nos. 1 and 2, of turpentine, then dried them and handed them to me, and, after carefully noting that no pigment was left in the brushes, they were thoroughly worked into the next number of paint to be used. In this way no pigment was carried over from one paint to another.

SHELLACKING. Orange shellac was applied to knots on the bare wood of those panels used for paints Nos. 8 to 27, and over the priming coat on those panels used for paints Nos. 1 to 8. The shellac was applied by the inspector, Mr. Parthree. By this method we have two conditions of shellacking, from which we hope to draw inferences later on as to the best method of application.

PRIMING COAT.

A full quart can of paint as received was placed upon a correct set of balances and the gross weight was taken in grams and the weight of the paint as received was marked on the weighing sheets.

The can was then opened and the contents was poured into a half-gallon enamel pot and thoroughly broken up and stirred well to bring the mixture to thorough incorporation. The consistency was then noted and one-half of this paint was transferred to two half-pint friction top cans, which were sealed and marked with the number of the paint and name of the fence, and later on one set of these cans was sent to the Scientific Section, and the other sent to Committee E, of the American Society for Testing Materials, for future reference and analysis.

Proper reduction was made for the priming coat of the balance of the paint in the enamel pot, and it was then

ready for application. The brush used for the priming coat was thoroughly worked into the paint and then the pot, paint and brush were placed upon the balance and the weight taken by the official weigher in grams, using the metric system throughout in this test. The pot was then handed to the painter who applied the paint to one panel. After proper application, the brush, pot and paint were then handed back to the weigher and reweighed, the difference in weight being the weight of the paint in grams used on the panel, recording same on the weighing sheet, also the number of the panel upon which the paint was applied and the kind of lumber. This method of procedure was followed throughout the tests on every formula and on every panel.

The drying of the priming coat was noted every twenty-four hours on the different woods and the penetration was observed at the same time. The priming coat was allowed eight days to dry, and during this period inspection was made as to the drying.

At this period a black cross was stencilled upon the end of the middle board of each panel with lampblack. This was placed there in order that we might observe the hiding power of the different formulas on the second and third coats.

SECOND COAT.

The weather conditions prevailing during the application of the second coat were practically the same as during the first coat, and the temperature was noted every day. A new can of paint was used for each test on the second coat, and the method of weighing used in the first coat was followed throughout. The contents of a fresh can of paint was placed into the enamel pot and thoroughly broken up. The consistency was then carefully noted, and one pint was used for reduction, this reduction being recorded on a separate sheet. The reduction was made with oil and turpentine, taking into

consideration the formula and color of each paint. The consistency of the reduced paint was taken and carefully noted upon the data sheet. The covering was noted at the time of application and marked down. The penetration and drying were noted every twenty-four hours. This coat was allowed about nine days to dry, with frequent inspection.

THIRD COAT.

A new package of paint was opened and the entire contents was poured into the enamel pot, and after being thoroughly broken up and mixed, was used as received, without reduction wherever possible, and where reduction was necessary, it was made and carefully noted. The same system of weighing was used in the third coat as on the first and second coats. The covering and working of the paint was carefully noted at the time of application, and inspection of the covering was made after the work was finished and the panel ready to be screwed to the fence. At this time glass slides of plain and orange glass, in frames, were placed on different panels.

LEADS. The leads were reduced by the ounce system, each ounce of vehicle added to 12½ oz. of paste lead as received representing one gallon of vehicle to 100 lbs. lead. The amount of reduction was carefully noted, and the reduction compared with the consistency of the mixed paints used, thus giving a test throughout of equal conditions and applications.

GENERAL. This work was conducted in a large automobile garage, in the rear of a large hotel at Atlantic City, provided for this work. Benches and work tables and the proper accessories for this work were provided. The doors were locked and no one was allowed in the building except in the presence of the inspectors.

I believe this test to have been carried out in a practical and scientific manner and to the best of my knowledge will show interesting results, which will be of great

benefit from a technical standpoint. It has been my endeavor to do this work in a thorough and conscientious manner, and to treat everything with fairness to the best of my ability.

Thanking you for your confidence in my ability, I remain,

(Signed)

J. B. CAMPBELL.

Wilmington, Delaware, March 16, 1908.

Mr. Robert S. Perry, Director,
Scientific Section,

Paint Manufacturers' Association of the U. S., Philadelphia, Pa.

DEAR SIR:—I have acted in the capacity of official inspector for Committee E, of the American Society for Testing Materials, during the painting of the panels of the test fence at Atlantic City, and have been present throughout the work.

The work was carried on in a systematic manner, and the treatment of the various paints and leads was made under equal conditions, and in a careful and practical manner, giving every panel and paint equal consideration. I have endeavored, to the best of my ability, to see that everything has been done in a fair manner, and I believe the experiments will prove of great interest and benefit.

Mr. Campbell, inspector for the Paint Manufacturers' Association, who had charge of the reduction, has worked in a fair and conscientious manner, and no information was given out by anyone connected with this work as to the number of paint, or the number of the formulas. Everything was kept under strict surveillance. Mr. Pablo, painter for the Master Painters' Association of Philadelphia, and Mr. Campbell were present with me throughout the work. Hoping to be of further service, I am,

Very truly yours,

JAMES T. PARTHREE.

Philadelphia, March 16, 1908.

Mr. Robert S. Perry, Director,
Scientific Section,

Paint Manufacturers' Association of the U. S., Philadel-
phia, Pa.

DEAR SIR:—I have acted as painter for Mr. Butler, who was appointed official painter of the Atlantic City Test Fence by the Master Painters' Association of Philadelphia, and have been present with Mr. Campbell and Mr. Parthree throughout the work.

I have been careful and conscientious in my work, and I believe that every endeavor was made on the part of every one connected with the work to treat all the paints and all the work with equal care and attention. The test was practical from every standpoint.

Hoping to be of further service, I am,

Very truly yours,

GEORGE PABLO.

To Mr. R. S. Perry, Director,
Scientific Section,

Paint Manufacturers' Association of the U. S.

GENERAL REPORT OF PAINT TESTS
MADE AT CARNEGIE TECHNICAL
SCHOOLS, PITTSBURG, PA.

On January 30th, the work on the Pittsburg test fence was started. The weather was fairly good and the temperature was 30° F. inside the building where the paint was applied. The work was all done in the presence of the official inspector and weigher, Mr. C. D. Alexander, acting for Dr. James of the Carnegie Technical Schools; Mr. S. Ballinger, painter for Mr. A. C. Rapp, who was appointed official painter of the fence by the Master Painters' Association of Pittsburg, and myself, and was under the supervision of Mr. H. A. Gardner, chemist of the Scientific Section.

The panels were arranged in sets of six—first, two white pine; second, two yellow pine; and third, two cypress—by Mr. Alexander, and in their proper sequence

with regard to the consecutive numbers branded on these panels.

PAINTS. The various paints were received in quart cans labeled "Paint Manufacturers' Association," and the number of the paint contained therein, but with no information regarding the name of the manufacturer who prepared the paint or other directions or information regarding reduction, etc. The various white leads used were received in kegs of 12½ lbs. each.

BRUSHES. A heavy 7-0 round bristle brush was used for the priming coat, so that the paint could be thoroughly worked into the wood. On the second and third coats a three-inch flat chisel brush was used, and washed and cleaned thoroughly in two washes of turpentine after applying one number of paint on all six panels in one color. The painter then worked out all the paint from the brush and set the brush in pot No. 1, turpentine. The inspector then washed them thoroughly in pots Nos. 1 and 2, of turpentine, then dried them and handed them to me, and, after carefully noting that no pigment was left in the brushes, they were thoroughly worked into the next number of paint to be used. In this way no pigment was carried over from one paint to another.

SHELLACKING. Orange shellac was applied to knots on the bare wood of those panels used for paints Nos. 8 to 27, and over the priming coat on those panels used for paints Nos. 1 to 8. The shellac was applied by Mr. Ballinger and myself. By this method we have two conditions of shellacing from which we hope to draw inferences later on as to the best method of application. The shellacing on these panels was not so carefully done as on the Atlantic City fences, as I wish to determine for your satisfaction, whether some combinations would not stain or turn yellow or black more rapidly than others, also continue to stain to a greater area around the knot or sappy places. This information has been asked of me

several times and I have not been able heretofore to answer same to my own satisfaction, and I believe this will be a good demonstration of what we wish to determine.

PRIMING COAT.

A full quart can of paint as received was placed upon a correct set of balances and the gross weight was taken in grams and the weight of the paint as received was marked on the weighing sheets.

The can was then opened and the contents was poured into a half-gallon enamel pot and thoroughly broken up and stirred well to bring the mixture to thorough incorporation. The consistency was then noted and one-half of this paint was transferred to two half-pint friction top cans, which were sealed and marked with the number of the paint and name of the fence, and later on one set of these cans was sent to the Scientific Section, and the other sent to the laboratories of the Carnegie Technical Schools, for future reference and analysis.

Proper reduction was made for the priming coat of the balance of the paint in the enamel pot and it was then ready for application. The brush used for the priming coat was thoroughly worked into the paint and then the pot, paint and brush were placed upon the balance and the weight taken by the official weigher in grams, using the metric system throughout in this test. The pot was then handed to the painter who applied the paint to one panel. After proper application, the brush, pot and paint were then handed back to the weigher and reweighed, the difference in weight being the weight of the paint in grams used on the panel, recording same on the weighing sheet, also the number of the panel upon which the paint was applied and the kind of lumber. This method of procedure was followed throughout the tests on every formula and on every panel.

The drying of the priming coat was noted every twenty-four hours on the different woods and the pene-

tration was observed at the same time. The priming coat was allowed eight days to dry and during this period inspection was made as to the drying.

At this period a black cross was stencilled upon the end of the middle board of each panel, with lampblack. This was placed there in order that we might observe the hiding power of the different formulas on the second and third coats.

SECOND COAT.

The weather conditions prevailing during the application of the second coats were practically the same as during the first, and the temperature was noted every day. A new can of paint was used for each test on the second coat, and the method of weighing used in the first coat was followed throughout. The contents of a fresh can of paint was placed into the enamel pot and thoroughly broken up. The consistency was then carefully noted and one pint was used for reduction, this reduction being recorded on a separate sheet. The reduction was made with oil and turpentine, taking into consideration the formula and color of each paint. The consistency of the reduced paint was taken and carefully noted upon the data sheet. The covering was noted at the time of application and marked down. The penetration and drying was noted every twenty-four hours. This coat was allowed about nine days to dry, with frequent inspection.

THIRD COAT.

A new package of paint was opened and the entire contents was poured into the enamel pot, and after being thoroughly broken up and mixed, was used as received, without reduction wherever possible, and where reduction was necessary it was made and carefully noted. The same system of weighing was used in the third coat as on the first and second coats. The covering and working of the paint was carefully noted at the time of applica-

tion and inspection of the covering was made after the work was finished and the panel ready to be screwed to the fence. At this time glass slides of plain and orange glass, in frames, were placed on different panels.

LEADS. The leads were reduced by the ounce system, each ounce of vehicle added to 12½ oz. of paste lead as received representing one gallon of vehicle to 100 lbs. lead. The amount of reduction was carefully noted, and the reduction compared with the consistency of the mixed paints used, thus giving a test throughout of equal conditions and applications.

GENERAL. This work was conducted in the basement of the Margaret Morrison Carnegie Building, provided for this work. Benches and work tables and the proper accessories for this work were provided. The doors were locked and no one was allowed in the building except in the presence of the inspectors.

I believe this test to have been carried out in a practical and scientific manner, and to the best of my knowledge will show interesting results, which will be of great benefit from a technical standpoint. It has been my endeavor to do this work in a thorough and conscientious manner, and to treat everything with fairness to the best of my ability.

Thanking you for your confidence in my ability, I remain,

J. B. CAMPBELL,
Inspector.

Pittsburg, Pa., April 1, 1908.

Mr. Robert S. Perry, Director,
Scientific Section,
Paint Manufacturers' Association of U. S., 3500 Gray's
Ferry road, Phila.

DEAR SIR:—I have acted in the capacity of official inspector for Dr. James, chairman of the committee appointed by the Carnegie Technical Schools to supervise

the painting tests which were carried on upon the school grounds and recently finished.

I was present with Mr. Campbell, inspector of the Paint Manufacturers' Association, and Mr. Ballinger, painter for Mr. Rapp, who was appointed official painter of the fence by the Pittsburg branch of the Master Painters' Association, and was with these gentlemen throughout the work. This work was carried on in a most systematic manner, and the treatment of the various paints and leads was equally careful and unbiased in every way, and I believe that we all did our best to give every panel and every paint equal attention and consideration. The weighing, reductions, applications and drying were all observed with great care, and I wish to state that the work has been carried on in a fair and conscientious manner from start to finish.

No information was given out by anyone connected with this work as to the numbers of the paints or panels, and everything was kept under strict surveillance, the door of the shed, in which the work was carried on, being locked after working hours.

Very truly,

C. D. ALEXANDER.

Pittsburg, Pa., April 1, 1908.

Mr. Robert S. Perry, Director,
Scientific Section,

Paint Manufacturers' Association, 3500 Gray's Ferry
road, Phila.

DEAR SIR:—I have acted as painter for Mr. Rapp, who was appointed official painter of the Pittsburg test fence by the Master Painters' Association of Pittsburg, and I have been present with Mr. Campbell and Mr. Alexander throughout the work on the Pittsburg fence.

I have been careful and conscientious in my work, and I believe every endeavor was made on the part of all connected with the work to treat everything with equal care and attention.

Very truly yours,

SAMUEL BALLINGER.

METHODS
for the
Analysis
of the
Vehicle Constituents
of **Paint**



Methods for the Analysis

of the

Vehicle Constituents of Paint



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PUBLISHED BY THE SCIENTIFIC SECTION
PAINT MANUFACTURERS' ASSOCIATION
OF THE UNITED STATES

TO THE paint chemist and manufacturer desirous of securing in condensed form for ready reference reliable methods for the analysis of the vehicle constituents of paint, such as oil, turpentine, varnish, etc., we present this pamphlet. We hope that the invaluable information that we have compiled will stimulate further investigations along the same lines, which offer so many opportunities for research.

R. S. PERRY,
Director Scientific Section
Paint Manufacturers' Association
3500 Grays Ferry Road
Phila., Pa.

EXTRACTS FROM "SOME TECHNICAL METHODS OF TESTING
MISCELLANEOUS SUPPLIES," AS PUBLISHED IN
BULLETIN 109, U. S. DEPARTMENT OF
AGRICULTURE

BY PERCY H. WALKER, Chief, Contracts Laboratory

LINSEED OIL

1. Specific Gravity

Determine with a pycnometer or spindle at 15.6° C.

2. Viscosity

Use the Engler method, making the determination at 20° C.

3. Flash Point, Open Cup

Set a nickel crucible 60 mm. in diameter at the top, 40 mm. in diameter at the bottom, and 60 mm. in height in a hole in the middle of a sheet of asbestos board 200 mm. square. The bottom of the crucible should project about 25 mm. through the asbestos. Support the asbestos on a tripod and suspend a thermometer reading to 400° C. in degrees in the center of the crucible, so that the lower end of the thermometer is 10 mm. from the bottom of the crucible. Then pour in the oil until its level is 15 mm. below the top of the crucible. Place a Bunsen burner below the crucible and regulate the size of flame so that the thermometer rises 9° a minute. As a test flame use an ordinary blowpipe attached to a gas tube. The flame should be about 6 mm. long. Begin testing when the temperature of the oil reaches 220° C., and test for every rise of 3°. In applying the test move the flame slowly across the entire width of the crucible immediately in front of the thermometer and 10 mm. above the surface of the oil. The flash point is the lowest temperature at which the vapors above the oil flash and then go out.

4. Fire Point

After noting the temperature at which the oil flashes continue the heating until the vapors catch fire and burn over the surface of the oil. The temperature at which this takes place is the fire point. In determining the flash point note the behavior of the oil. It should not foam or crack on heating. Foaming and cracking are frequently caused by the presence of water.

5. Turbidity

Note whether the oil is perfectly clear or not.

6. Foots

Let a liter of the oil stand in a clear glass bottle for eight days, and then note the amount of residue formed. The highest grades of oil show no turbidity or foots by this test. The claim is made that sometimes what would be called foots by the above method is due to the freezing out of fats of rather high melting point. When a sufficient amount of the sample is available, heat one portion to 100° C. and set it aside for the determination of foots together with a sample just as it is received.

7. Break

Heat 50 cc. of the oil in a beaker to 300° C. Note whether the oil remains unchanged or "breaks," that is, shows clots of a jelly-like consistency. Note also the odor of the oil after cooling, and by rubbing it on the hands; a small amount of fish oil may be detected in this way.

8. Moisture

Heat about 5 grams of oil in an oven at 105° for 45 minutes; the loss in weight is considered as moisture. This determination is, of course, not exact, as there is some oxidation. When more accurate determination is desired, perform the whole operation in an atmosphere of hydrogen.

9. Ash

Burn about 20 grams of oil in a porcelain dish and conduct the ashing at as low a temperature as possible. The best oil should contain only a trace of ash. An amount as large as 0.2 per cent would indicate an adulterated or boiled oil. Examine the ash for lead, manganese and calcium.

10. Drying on Glass

Coat glass plates 3 by 4 inches with the oils to be examined, expose to air and light, and note when the film ceases to be tacky. A good oil should dry to an elastic coherent film in 3 days. Varying conditions of light, temperature and moisture have such an influence on drying tests that for comparison of one linseed oil with others all samples must be run at the same time.

11. Drying on Lead Monoxid

Livache's test calls for precipitated lead, but litharge gives equally good results. Spread about 5 grams of litharge over the flat bottom of an aluminum dish 2.5 inches in diameter and five-eighths of an inch high, weigh the dish and the litharge; distribute as evenly as possible over the litharge 0.5 to 0.7 gram of the oil, weigh exactly, expose to the air and light for 48 hours, weigh, and calculate the gain in weight to percentage based on the original weight of the oil taken.

12. Acid Number

Weigh 10 grams of oil in a 200 cc. Erlenmeyer flask, add 50 cc. of neutral alcohol, connect with a reflux air condenser, and heat on a steam bath for half

an hour. Remove from the bath, cool, add phenolphthalein, and titrate the free acid with fifth-normal sodium hydroxid. Calculate as the acid number (milligrams of potassium hydroxid to 1 gram of oil). The acid number varies with the age of the oil, and should be less than 8, though when the oil is refined with sulphuric acid it may show a higher acid number. Test for sulphuric acid.

13. Saponification Number

Weigh from two to three grams of oil in a 200 cc. Erlenmeyer flask, add 30 cc. of a half-normal alcoholic solution of potassium hydroxid, connect with a reflux air condenser, heat on a steam bath for an hour, then titrate with half-normal sulphuric acid, using phenolphthalein as indicator. Always run two blanks with the alcoholic potash. From the difference between the number of cubic centimeters of acid required by the blanks and the determinations, calculate the saponification number (milligrams of potassium hydroxid to 1 gram of oil). The saponification number should be about 190.

14. Unsaponifiable Matter

As the saponification varies somewhat in pure oil, it is sometimes advisable to make a direct determination of unsaponifiable matter. Saponify from 5 to 10 grams of oil with alcoholic potassium hydroxid (200 cc. of a half-normal solution) for an hour on a steam bath using a reflux condenser. Then remove the condenser and evaporate the alcohol as completely as possible; dissolve the soap in 75 cc. of water, transfer to a separatory funnel, cool, shake out with two portions of 50 cc. each of gasoline 88° B., wash the gasoline twice with water, evaporate the gasoline, and weigh the unsaponifiable matter. The unsaponifiable matter in raw linseed oil should be below 1.5 per cent; in boiled oil it is somewhat higher but should be below 2.5 per cent.

15. Iodin Number

Weigh in a small glass capsule from 0.2 to 0.25 gram of oil, transfer to a 350 cc. bottle having a well-ground stopper, dissolve the oil in 10 cc. of chloroform and add 30 cc. of Hanus solution; let it stand with occasional shaking for one hour, add 20 cc. of a 10 per cent solution of potassium iodid and 150 cc. of water, and titrate with standard sodium thiosulphate, using starch as indicator. Blanks must be run each time. From the difference between the amounts of sodium thiosulphate required by the blanks and the determination, calculate the iodine number (centigrams of iodine to 1 gram of oil). The iodine number of raw linseed oil varies from 175 to 193, though Gill states that a pure raw oil may give a value as low as 160. Boiled oil may be very much lower.

Make the Hanus solution by dissolving 13.2 grams of iodine in 1,000 cc. of glacial acetic acid which will not reduce chromic acid, and adding 3 cc. of bromine.

16. Rosin Oil (Liebermann-Storch Test)

To 20 grams of oil add 50 cc. of alcohol, heat on a steam bath for 15 minutes, cool, decant the alcohol, evaporate to dryness, add 5 cc. of acetic anhydride, warm, cool, draw off the acetic anhydride, and add a drop of sulphuric acid, 1.53 specific gravity. Rosin oil gives a fugitive violet color.

SPIRITS OF TURPENTINE

1. Color

The best quality of spirits of turpentine should be water white.

2. Specific Gravity

Determine the specific gravity with a pycnometer or Westphal balance at 20° C. Pure gum turpentine should have a density between 0.862 and 0.875. Wood turpentine may, however, range from 0.860 to 0.910 or even higher.

3. Distillation

Connect a distilling flask of 150 cc. capacity with a condenser having a thermometer. Introduce 100 cc. of turpentine and heat with a Bunsen burner. The boiling point should be about 156°, and 95 per cent should distill over between 153.5° and 165.5° C.

4. Residue on Evaporation

Evaporate 10 grams on the steam bath; the residue should be less than 2 per cent.

5. Refraction Index

Determine with a Zeiss direct reading refractometer at 20° C. The index of refraction for gum turpentine should be from 1.4690 to 1.4740; for wood turpentine, 1.4685 to 1.5150.

6. Action of Sulphuric Acid (Polymerization)

Measure 6 cc. of turpentine in a stoppered, thin-walled tube graduated to 0.1 cc. (carbon tubes). Place the tube in cold water and pour in slowly a mixture of four parts of strong sulphuric acid and one part of fuming sulphuric acid. Add the acid slowly, and avoid an excessive rise in temperature. Shake the tube so as to mix the turpentine and the acid, add finally about 20 cc. of the acid, stopper the tube, mix thoroughly, cool, allow to stand 30 minutes, and note the volume of unpolymerized oil that collects on top of the acid layer. Then let stand for 18 hours and again note the volume. A pure turpentine should show less than 0.3 cc. unpolymerized at the end of 30 minutes, and less than 0.5 after 18 hours.

7. Spot Test

Place a drop on filter paper and allow it to dry at room temperature; it should leave no stain.

8. Flash Point

Support a crucible, such as is used in determining the flash point of linseed oil, in a vessel of water at 15° to 20° C.; the water should cover about two-thirds of the crucible. Fill the crucible to within about 2 cm. of the top with turpentine, insert a thermometer and heat the water bath slowly, 1° per minute. Begin at 37° and test for the flash at each rise of 0.5°. The turpentine should not flash under 40.5° C.

VARNISH

The methods of analysis for varnish are far from satisfactory. The following method, slightly modified, is one devised by S. S. Voorhees, and while not absolutely satisfactory, is probably the best available.

1. Insoluble Gums

Weigh 2 grams of the varnish into a weighed 150 cc. Erlenmeyer flask, add 2 cc. of chloroform, and then 100 cc. of 88° B. gasoline; add the gasoline gradually, shaking constantly so as to avoid any precipitation, until 15 cc. are added. Allow to stand over night in a cool place. The gums will adhere to the bottom and side of the Erlenmeyer flask; decant into a weighed beaker and wash with a little 88° gasoline. Dry for two hours at 105° C. and weigh as insoluble gums.

2. Soluble Gums and Linoxyn

Evaporate the gasoline extract and dry the residue for 168 hours at 100° to 105° C., or to constant weight and weigh. This treatment should convert all linseed oil into linoxyn. Add 15 cc. of chloroform and digest over night to dissolve the gums but not the linoxyn. Filter through a wad of absorbent cotton into a weighed beaker, evaporate the chloroform, dry for 2 hours at 105°, and weigh as soluble gums. Linoxyn is obtained by difference from the first weight.

3. Acid Value

Determine the acid value in the usual way on 10 grams of the varnish. After getting the acid value, decant the alcohol, evaporate, and apply the Liebermann-Storch test for rosin.

4. Ash

Determine the ash on 10 grams (in a porcelain dish). Determine the reaction of ash with litmus paper; if alkaline, test for lime. It is sometimes well to determine lime, a large amount of which indicates rosin.

5. Miscellaneous

Volatile oils, and metals are determined as in the analysis of the vehicle under mixed paints

It is not possible from such an examination as has been described to decide on the value of a varnish for any particular purpose. An examination of the varnish film should always be made. The film is best made by flowing the varnish on glass, and films should be dried in both a horizontal and a vertical position at a uniform temperature, 38° C. Note the time of setting the appearance, the hardness and toughness of film. Other tests may also be applied.

A METHOD OF ANALYZING SHELLAC *

BY PARKER C. McILHINEY

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The method of analysis which is in most common use at the present time, both in England and in the United States, for the determination of the amount of rosin in shellac, is an indirect method depending upon the different powers of a shellac and of rosin to absorb iodine from a suitable solution. Different operators prefer different methods of making this test, some preferring to use the old Hubl method, and others the more modern Wijs method, as modified by Langmuir. Either of these methods is capable of giving reasonably satisfactory results, although the Langmuir method is certainly much to be preferred, both on the score of accuracy and of speed. Another method which is in use is that proposed by Parry, depending upon the solubility of the resinate of silver made from common resin, in ether, while the corresponding resinates from shellac are insoluble. This method labors under several disadvantages and sources of error, of which the two principal ones are the solubility of the unsaponified portion of the shellac in ether, and the danger of a decomposition of the resinate of silver before it can be separated and determined.

A direct method of separating shellac and rosin and recovering the rosin, at least, in a substantially unchanged form, is greatly to be desired, and several experimenters have attempted to make such a separation by taking advantage of the solubility of rosin in petroleum ether, a solvent in which shellac is insoluble. No method of extracting from even a finely pulverized sample of shellac the portion soluble in petroleum ether seems to be capable of removing more than a small part of the rosin contained in the sample.

Shellac dissolves in alcohol, except for the wax contained in it; petroleum ether dissolves to some extent in alcohol and it was thought that by first dissolving the shellac to be analyzed in alcohol, then adding to the solution all the petroleum ether which it would dissolve, and then adding water, so as to so dilute the alcohol that it would no longer have any material solvent power upon either rosin or shellac, there should result a separation of the dissolved petroleic ether containing in solution the rosin and the wax, but free from the resinous constituents of the shellac. Upon trying this process, it appeared that it was correct in principle, but that on account of the limited solubility of petroleum ether in alcohol, the separation was not quite complete. Upon substituting for ordinary alcohol, glacial acetic acid, or absolute alcohol, in which the sample of shellac to be examined is dissolved and then adding to it petroleum ether, which is miscible in all proportions with acetic acid, or absolute alcohol,

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it was found practicable to combine with the rosin and the wax so large an amount of petroleum ether, that upon adding water, an almost complete separation of the rosin and wax from the resinous part of the shellac could be effected.

Based upon these facts, the following process was devised: Dissolve in 20 cc. of glacial acetic acid (about 99 per cent.), or the same volume of absolute alcohol, 2 grams of the sample to be analyzed. This requires a gentle heat. Add to the solution, after cooling, 100 to 300 cc. of petroleum ether, boiling under 80°. This addition of petroleum ether should be made slowly, because the addition of so large an amount of petroleum ether precipitates from its solution a part of the shellac, combined, apparently, in case acetic acid was the original solvent, with acetic acid to form a liquid precipitate. It is manifestly desirable that this precipitation of part of the shellac should not be effected by too sudden an addition of petroleum ether, as it might then contain some rosin carried down mechanically with it.

We now have a solution containing both petroleum ether and glacial acetic acid, or absolute alcohol, and containing in it, in solution, all the rosin, all the wax and most of the resinous part of the shellac. Add now to this solution, drop by drop, 100 cc. of water, agitating the liquid during the addition. The water "unites with" the alcohol or acetic acid, and separates from the liquid the petroleum ether with whatever is soluble in petroleum ether. This includes the rosin and the wax. The shellac is also precipitated, but as it is insoluble in petroleum ether it remains as a precipitate suspended in the diluted alcohol or acetic acid. The separation of the two liquids takes place very rapidly, and it is an easy matter to effect a complete separation of the two layers in a separating funnel. The petroleum ether layer is washed once or twice with water and then filtered through a dry paper into a weighed flask, from which the petroleum ether is then distilled off, leaving the residue of rosin mixed with wax, which is weighed. To the weighed residue neutral alcohol is added, and the flask heated to dissolve the rosin in the alcohol. The liquid is then titrated with N/5 or N/10 caustic potash. This gives a measure of the amount of rosin present, as the average combining equivalent of rosin does not vary greatly from 346. This is the figure used for this titration in the Twitchell process. It is much better, however, not to depend upon his determination of the rosin but to proceed to an actual separation by adding to the neutralized alcoholic solution, a distinct excess of alkali, and a sufficient quantity of petroleum ether; the mixture is then transferred to a separating funnel, thoroughly agitated, and some water added. The liquids are then separated, the petroleum ether layer being washed with water, and the alcoholic solution of the rosin extracted once more with petroleum ether. The petroleum ether solutions are then united, the petroleum ether distilled off, and the residue of wax weighed. The alcoholic solution containing the rosin is then boiled until the alcohol has been expelled, and, if necessary, a further addition of water made; then dilute hydrochloric acid is added, so as to precipitate the rosin. This should be done in a weighed flask; the acidified liquid can now be decanted off through a wet filter paper so as to leave behind in the flask the major part of the rosin, which is washed with water. The remainder of the rosin upon the filter paper after sufficient washing, is extracted with petroleum ether back into the weighed flask from which the water has been decanted as perfectly as possible. Upon distilling off the petroleum ether, the rosin is left behind in a condition to weigh. If the whole of the last traces of water have

not been removed by the distillation with petroleum ether, it is well to add a further quantity of dry petroleum ether and distil again.

Attempts were made to use other solvents, particularly coal tar benzine instead of petroleum ether. It was found, however, that benzine dissolved considerably more out of the shellac than the wax.

If it is desired to determine only the rosin in the shellac, it is unnecessary to distil off all the petroleum ether from the solution containing the wax and the rosin. This solution may, instead, be treated directly with an alkali capable of combining with the rosin, while leaving the wax unattached. The most convenient method which I have found for accomplishing this is to add to the petroleum ether solution, after filtering it to remove from it anything which it may contain in suspension, a solution of sodium hydroxide in absolute alcohol. Such a solution I have found it convenient to make by dissolving in ordinary 95 per cent. alcohol the appropriate amount of metallic sodium. Such a solution, when added to the petroleum ether solution, mixes perfectly with it, and the alkali combines with the rosin, and the mixed solution allows the saponified rosin to be extracted from it by agitation with water, or better, with slightly diluted alcohol. Instead of using a solution of sodium hydroxide in absolute alcohol, it should be possible to use the method of separating rosin from neutral substances in petroleum ether solution, that is used in the Twitchell process of determining rosin in admixture with fatty acid. This consists in agitating the petroleum ether solution with an alkaline aqueous solution, containing some alcohol, made by dissolving one gram of potassium hydroxide with 10 cc. of alcohol in water, and diluting to 100 cc. I have found the other method of procedure advantageous, however, and believe it to give a more exact separation. The solution drawn off from the petroleum ether, after extraction by alkali and containing in solution the rosin, combined with potassium or sodium, together with whatever alcohol has been used to promote the combination and to facilitate the mechanical separation of the two liquids, is heated for some time to remove the alcohol, and is then acidified with hydrochloric or with sulphuric acid to precipitate the rosin. The precipitated rosin is then weighed as before.

Without entering into a discussion of the exact chemical composition of shellac wax, it may be proper to state that the wax may be separated commercially from shellac by two essentially different methods, which will probably give waxes having somewhat different compositions. If the shellac is dissolved in an alkaline solution and the wax which remains in suspension is filtered out, it is probable that different results will be obtained from what would be obtained by the other process, consisting of a solution of the shellac in alcohol, and filtration of the solution to remove the wax which will then remain in suspension. It is to be expected that these two processes of solution would leave, in the undissolved wax, small amounts of ingredients of different characters, and, furthermore, the alcohol used in the second process would dissolve small amounts of the wax which would probably be quite insoluble in an alkaline aqueous solution. Again, it is quite probable that a caustic solution would behave towards shellac wax somewhat differently from a dilute carbonate solution. For the sake of uniformity and simplicity, I am assuming that shellac wax is quite free, when pure, from all acid substances capable of uniting with free alkali. It is, nevertheless, true that the user of shellac who wishes to have a determination made of the amount of wax which it contains, usually

desires this information in order that he may know how much of the shellac will remain undissolved in alcohol. This amount of insoluble wax will, of course, vary to some extent, depending upon the strength of the varnish that he prepares with it, that is to say, the number of pounds of shellac which he uses to a gallon of alcohol. As the analyst can hardly be expected to take account of this in making his test, it appears more rational to regard as wax, the whole of those matters contained in the shellac that remain insoluble in an alkaline solution.

In making a determination of the amount of wax in a sample of shellac, by this method, it is to be observed that some constituent of shellac wax is evidently only difficultly soluble in petroleum ether. Upon submitting several portions of the same lot of shellac to analysis in this way, the only difference made in the different determinations being that varying amounts of petroleum ether were used, the series of analysis gave, with increasing amounts of petroleum ether, increasing percentages of wax, until the proportion of about 125 to 150 cc. of the solvent to 1 gram of a shellac containing about 5 per cent. of wax was reached. It may be that by using some other solvent such as benzine for the determination of wax in this way, a smaller amount will suffice, but as it seldom happens that only wax without rosin is to be determined, petroleum ether is the most generally applicable solvent. The solubility of rosin in petroleum ether is so easy and complete that no difficulty is experienced in extracting from 2 grams of shellac 50 per cent. of rosin, using 100 cc. of petroleum ether.

Whenever in the course of an analysis by this method a quantity of material is separated by acidifying the aqueous solution which should contain the rosin, its identity may be established with some certainty by determining its iodine figure by the Langmuir method, and its acidity by titrating with alkali in alcoholic solution.

The petroleum ether referred to here is a solvent made by redistilling 71° Bé. benzine, separating for use that part which distills below 80°. This fraction constitutes a large proportion of 71° benzine, and such a redistillation gives, at a comparatively small cost, a satisfactory solvent for the purpose. If a determination of only the rosin is desired, it is, of course, unnecessary to be very particular as to the volatility of the solvent used, as it is unnecessary in such case to distil it off before extracting the rosin by alkali.

By treating pure shellac according to this process, it is possible to separate from it a small amount, sometimes as much as 1 per cent., of materials soluble in petroleum ether. This small amount of resinous matter, when examined, proves to be something essentially different from common rosin. Its odor and its low iodine figure indicate that it is some resinous constituent of shellac, perhaps a small amount of the major constituent, which is slightly soluble in petroleum ether. As it is difficult to imagine that by this process rosin if a normal constituent of pure shellac would escape detection, and as the small amount of resinous matter here obtained is essentially different from rosin, it is reasonable to conclude that, contrary to the idea held by many, common rosin or a material similar to it, is not a natural constituent of pure shellac, but that any rosin or colophony, which can be separated in a state of reasonable purity from the sample of shellac, was originally added to the shellac, as an adulterant.

The process here described allows the analyst to separate in a form convenient for exhibition either as evidence in court or as an ocular demonstration for his client, any rosin which may have been added as an adulterant to shellac.

Shellac varnishes may contain, besides true shellac, not only rosin but other gums and resins soluble in alcohol. It becomes, therefore, a matter of interest to ascertain how some of these other resins behave when treated by this process. Two samples of manilla, when treated, using absolute alcohol as the first solvent, gave respectively, 41.2 and 43.3 per cent of matter soluble in petroleum ether. The acidity of these two lots of matter soluble in petroleum ether was in the case of the first sample such that 1 cc. of normal alkali neutralized 411.7 milligrams and in the case of the second 470.7 milligrams. Two samples of Kauri gave, respectively, 37.9 and 27.0 per cent. Upon titrating with standard alkali these portions soluble in petroleum ether, it appeared that 1 cc. of normal alkali was capable of neutralizing 903.6 mg. and 742.5 mg., respectively. Of Sandarac, two samples, when similarly analyzed, gave 34.96 and 36.19 per cent., having such an acidity that of the first 541.2 mg. would neutralize 1 cc. normal alkali, and of the second, 552.5 mg. would neutralize 1 cc. Of Dammar, 89.9 per cent. proved to be soluble, while the resin of *Shorea roberta*, a sample of which was kindly sent by Mr. W. Risdon Criper, of Calcutta, gave 69.5 per cent. of soluble matter.

A number of attempts were made to affect a satisfactory separation of the wax before separating the rosin from the shellac. It was found, however, that on account of the solubility of wax in alcohol and in glacial acetic acid, this separation could not well be made by filtering out the wax before the addition of petroleum ether. Neither attempts which were made to separate the wax by a preliminary solution of the shellac in aqueous alkali successful in furnishing a method that at all approached in feasibility to the method already described.

145 E. 23d St., New York City.

THE ANALYSIS OF OIL VARNISHES *

BY PARKER C. MCILHINEY

Of the materials used in construction, few, if any, present more difficult problems in their testing and analysis than oil varnishes. Any rational system of testing varnishes to determine their suitability for a given use and their resistance to the destructive effects of exposure to the elements, will take account among other tests of a chemical analysis to determine the ingredients of the varnish and proportions in which they are combined. It is unfortunate that there is not, at the present time, any method of analysis which will determine with any reasonable degree of accuracy the proportions in which the oil, hard gum and common rosin have been combined to form the non-volatile base from which the varnish is produced by dilution with turpentine or other volatile oil. The proportion of volatile oil in the varnish may be determined by distilling the solvent off with steam at a temperature a little above the boiling point of water and then separating the volatile oil from the aqueous part of the distillate and weighing or measuring it. Its further examination need not be entered upon here since methods of analysis of such volatile oils as are likely to be used as thinners for varnish are how generally known and are described at length in such standard works as *Allen's Commercial Organic Analysis* and the books on paints and varnishes by Toch, Sabin, Holley and Ladd.

The separation of the hard gum from the oil and the common rosin is the problem which is difficult; the hard gum and the oil do not unite at all, practically, until the hard gum has been melted and from 15 to 25% of its weight driven off as vapor, the amount so lost depending upon the character of the gum. After this melting the linseed oil may be added if it has been previously heated hot enough to prevent it from chilling the melted gum. This mixture of oil and gum is usually at this stage heated for a shorter or longer time to complete the combination of the ingredients. The union of oil and hard gum which has been effected by this means cannot be broken up by any solvent, or perhaps it would be more accurate to say that after the combination between hard gum and oil has been successfully made and the mixture thinned with turpentine and stored for a few months, no solvent can be depended upon regularly to effect a separation of the two by its selective solvent action.

The process which is here described depends upon the fact that although the union between oil and hard gum is too intimate to be broken up by the selective solvent action of any solvent acting directly upon the original mixture, the combination may be broken up and the oil and gum brought back to more nearly their original condition before they were melted together, by submitting the mixture to the action of caustic potash in alcoholic solution and subsequently acidifying the solution of potash salts so formed. By this means there is obtained from hard gum varnishes a quantity of gum insoluble in petrolic ether

* A paper read at the recent convention of the American Society for Testing Materials.

very closely approximating the amount of hard gum actually existing in the varnishes, while the linseed oil is represented by its fatty acids which are readily soluble in this solvent unless they have been oxidized, in which case some of the fatty acids of the linseed oil will accompany the insoluble hard gum.

In carrying out the method an opportunity is given to determine not only the weight of the oil and of gum, but also the Koettstorfer figure and the percentage of glycerin in the mixture. All these data taken together give a basis for corroborating the main figures.

The process is carried out by weighing into an Erlenmeyer flask 2 to 10 grams of the varnish, adding a considerable excess of approximately half normal solution of caustic soda or caustic potash in very strong or absolute alcohol, distilling off the major portion of the solvent and redissolving in neutral absolute alcohol. The solution is then titrated with a solution of pure acetic acid in absolute alcohol, approximately half normal strength, to determine the amount of the excess of alkali present. From this the Koettstorfer figure is determined as the exact strengths of the acid and alkali solutions have been ascertained independently by comparison with known standards. A further quantity of the standard solution of acid in alcohol is added so as to exactly neutralize the total amount of alkali originally added. By this means the acid bodies liberated from their combinations with alkali are obtained in solution in strong alcohol. To this solution there is now added a sufficient quantity of petrolic ether to dissolve the oil acids and this petrolic ether being miscible with the strong alcohol, forms with it a homogenous liquid. Water is now added to the mixture in such amount as to so dilute the alcohol contained that it is no longer a solvent for fatty or resin acids; this addition of water causes the petrolic ether which was mixed with the alcoholic liquid to separate, carrying with it the fatty acids. The rosin goes with the fatty acids while the hard gum being insoluble in either the petrolic ether or in the very dilute alcohol separates in the solid state. The aqueous and ethereal layers are now separated in a separating funnel and each is washed, the watery layer with petrolic ether and the petrolic ether layer with water. The petrolic ether layer is now transferred to a weighed flask, the solvent distilled off and the residue of fatty acids and common rosin weighed. This latter is then examined further by Twitchell's method to determine the amount of rosin which it contains or it may be examined qualitatively in a number of ways to establish its identity.

The aqueous layer is freed from the suspended hard gum which it contains by filtering, and from any further quantity of gum which the weak alcohol may have retained in solution by evaporating off the alcohol and again filtering. The remaining aqueous liquid contains the glycerin and this is determined by the Hehner method with potassium dichromate in the method ordinarily used for examining spent soap lyes.

The hard gum is, according to this plan, precipitated in such a way that it adheres to the sides of the glass vessel in which the alcohol and petrolic ether mixture is diluted with water; the easiest method to weigh it is, therefore, to carry on the operation of dilution in a weighed glass vessel and then to dry and weigh the hard gum in this vessel. It frequently happens that some of the hard gum cannot be conveniently retained in this vessel, but that it must be filtered out on a weighed filter and the weight so found added to that of the main portion.

If the varnish contains non-volatile petroleum or other unsaponifiable

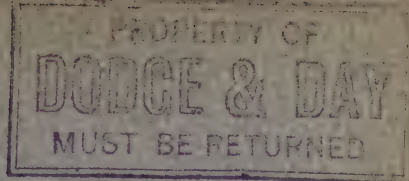
matter, it will naturally be included in the fatty and resin acids, and it would be necessary to saponify and extract the unsaponifiable matter from them while in the alkaline state; this operation is so familiar to chemists that it is only necessary here to call attention to the necessity for it in some cases.

It would naturally be expected that on account of the well-known insolubility of the oxidized fatty acids in petrolic ether, some of the acids of the linseed oil which had been polymerized by heat during the cooking of the varnish or which had been oxidized during the blowing process to which some linseed oil is subjected before making it up into varnish, would fail to dissolve and would be counted in with the hard gum instead of the linseed oil. It appears as a matter of fact that this source of error is of slight importance in the case of oil thickened by heat, but that the blowing process gives an oil which is not completely accounted for by the soluble fatty acids recovered. This difficulty may be largely overcome by taking advantage of the greater solubility of the oxidized fatty acids in alcohol as compared with the hard gum; the freshly precipitated gum contaminated with oxidized fatty acids is treated with a moderate quantity of cold alcohol of about 85% and allowed to digest for some time. The soluble matter so extracted is then recovered separately by evaporating off the alcohol.

The great variety of hard gum in use and in the methods of making them up into varnish make the problem one of great complexity. It is not to be expected that any one method of analysis or any single set of directions for carrying on the operation of making the analysis would be generally applicable, and it is not the intention in this paper to give such detailed instructions. The method described has, however, been found to give upon samples of known composition made up under conditions which intimate closely the conditions of practice in an ordinary varnish factory, results that were accurate to within reasonable limits.

Rosin, when present, is usually combined with lime in the proportion of about one part of lime to twenty parts of rosin. An examination of the mineral constituents of the varnish is, therefore, of some value; the extraction of the mineral bases may be effected by treating a quantity of the varnish somewhat thinned with benzine, with strong hydrochloric acid, and examining the aqueous liquid.

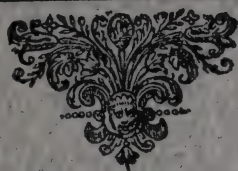
The amount of fatty acids obtained represents about 92.5% of the linseed oil. The identification of these fatty acids as belonging to linseed oil or to china wood oil may be satisfactorily accomplished in some cases, but there are undoubtedly many varnishes in which the analyst will be unable to identify and determine the oils. The identification of the hard gums after separating from the other constituents of the varnish is a matter for which no rules can be given. The odor and physical characteristics of the recovered gum are quite as important as the known chemical tests of which the acidity and the Koettstorfer figure are among the most important. The chemistry of these gums is as yet almost unknown, but in the near future it is likely that our knowledge both of the nature of these hard gums and of methods for separating them from the other ingredients of the varnishes of which they form a part, will be very greatly increased.



FIRST ANNUAL REPORT

of the

SCIENTIFIC SECTION



Respectfully

Paint Manufacturers' Associa-
: tion of the United States :

FIRST ANNUAL REPORT *of the*
SCIENTIFIC SECTION

Paint Manufacturers' Association of the
United States

3500 Grays Ferry Road, Philadelphia, Pa.

REPORT OF R. S. PERRY, Director.

Mr. Norris B. Gregg, Chairman,
Bureau of Promotion and Development,
Paint Manufacturers' Association of the U. S.

SIR:—Early in the year the appropriation made to carry on the work of the Scientific Section was entirely inadequate for the prosecution and continuance of investigations in the Chemical and Physical Testing Laboratories. These laboratory researches had to be discontinued, therefore, at a time when they were evolving from preliminary theoretical research, and even from the higher plane of applied and practical science, into a phase where they should be of immediate value to the practical manufacturer of paints, in his factory, and chemical and physical testing laboratories. Our work at this time was opening out into a field of great promise for the practical paint manufacturer and the progressive members of the Association were beginning to show their interest by following out our suggested accelerated testing of their products previous to the sale thereof.

Because of lack of funds, the work of the Laboratory Department was about entirely stopped, and the employment of laboratory chemists discontinued. With the exception of occasional work done by myself and by the Assistant Director in our laboratories, they have been practically inactive throughout the most important part of the year. The work of the Section from the time of the Laboratory lay-off in the spring has been concentrated upon the only work possible with the limited funds at hand, namely, the work of test fence construction and inspection, co-operative work with the Government officials on Nomenclature, the development of the new science of rust prevention and its practical application through the fences of steel, and such other work

Value of
Investigations

Discontinu-
ance of
Laboratory
Work

Recent Work

of a similar nature as the section has been confined to on account of the lack of funds.

Work for 1909

The work of the Section for 1909 will be confined to these latter activities alone, unless the Bureau is put into a position where it can appropriate the sum of \$6,000 for the resumption of the Laboratory Department of the Scientific Section. With this sum, chemists could be employed to continue the work which we have already laid as a foundation upon which to build the practical developments in the paint industry, that mean so much to the manufacturer in the future.

Laboratory
Dept.

Field Test
Dept.

The Field Test Department, in order to carry on the work already started and the work as outlined for the next year, will require an additional \$6,000. These sums would include the amount necessary to defray the general expenses of the Section, such as literature, publications, maintenance of library, maintenance of office and stenographer, and all traveling expenses in connection with general and scientific work.

Necessary
Appropriation

Therefore, in order that this Section may carry on these two departments, the Laboratory and Test Fence Department, and keep each member of the Association in touch with the latest technical developments of the scientific world and give satisfactory results, the sum of \$12,000 is needed, and I herewith make a request that the Bureau make a special effort to appropriate this sum to the Scientific Section.

Co-operative
Laboratory

Several members of the Association, who have not employed chemists to take care of their analytical work, have fallen in line with a suggestion made for the operation of a Commercial Laboratory employing a number of chemists. Subscription to this laboratory would entitle the paint manufacturer to receive the analyses of all products submitted, and his entire chemical work for a year would be offered at a lower rate than he could possibly attempt to have it done for elsewhere, and with accuracy and efficiency. However, this is a subject for the future, and until the Scientific Section gets better developed it would not be wise to undertake such a proposition. It is necessary for

the manufacturers to get in closer and better touch with our work and lend us more hearty support before we could inaugurate such an undertaking.

The manufacturers cannot place too high a value on the work which the Field Test Department has been conducting, and they will realize this to be true as soon as the results from the various test fences are published for their benefit. It is necessary to advance a better knowledge of the qualities, use and behavior of the more important pigments, and the work of the Laboratory is being confirmed in the work of the field tests in a thorough and practical manner. In these tests Silica, Aluminum and Magnesium Silicates, Barytes, Calcium Carbonate and Calcium Sulphate are some of the so-called inert pigments which are being tested out with the various white-base pigments, such as Zinc Oxide, White Lead, Sublimed Lead, Zinc Lead and Lithopone. To give an idea of how we gauge the value of each one of the inert pigments, and determine the safe limit of percentage for its use, you may consider as being applied to a series of panels a number of paints, each containing a different percentage of the pigment under consideration. The formula containing an excess of the pigment will show by future bad wear that the limit has been exceeded.

Field Tests

The total expenditures of the Scientific Section during the past year aggregate a sum of money which, if equally divided, would average each member of the Association about \$60, and I feel sure the value of our work will more than compensate for such an outlay.

The work on the proper transportation of explosives which we started grew to be a question requiring the attention of a competent and highly trained traffic manager, and the subject was turned over to Mr. Edwin F. Sellers, Chairman of the Transportation Committee, when that committee was established, and the Association is aware of the great amount of good this committee has been able to accomplish through the report of the Transportation Committee.

Transportation
of Explosives

At intervals we have sent out to the manufacturers bulle-

Publications

tins and pamphlets upon different subjects of interests, such as Can Standards, Methods of Analysis, Fence Reports, Nomenclature Tables, etc. The library of technical books, which we gathered and which has been the subject of several of our letters, has grown to be a most valuable adjunct to our work, and to the work of the Association members.

**Section
Reports**

In the printed report appended you will find a complete account of the work of the Laboratory for the year, and the results obtained from the valuable investigations which were started. There is appended a reprint of the First Report on Test Fences, and my report of 1907 to the Bureau, a comparison of which with this report will show the large amount of work which we have done. Mr. H. A. Gardner, Assistant Director, presents his general report on the Field Test Department, which has been particularly under his supervision.

Respectfully submitted,

R. S. PERRY, *Director.*

October 20, 1908.

Mr. R. S. Perry, Director,
Scientific Section,

Paint Manufacturers' Association of the U. S.

**Wooden
Test Fences**

SIR:—The largest test fences ever constructed for the practical trying out of paints are those erected by the Scientific Section of this Association at Pittsburg and at Atlantic City early in the spring of 1908. The members of the Association are already in touch with this work, the details being covered in the First Report on Test Fences, which was submitted to them four months ago, and which is appended as a reprint in this report.

**General Scope
of Work**

In the course of time, from the data which is obtained from the frequent inspections which are being made, inferences will be drawn as to the best combinations of pigments to use in order to make a satisfactory paint. Such a paint, when defined, would be one that has shown itself to possess during application good spreading, hiding and working

properties, and after a fair length of exposure and wear, permanency in color and in hiding properties, absence of chalking and checking, and a good condition of the surface that will allow of repainting.

If we discover that certain formulæ which we have applied to the fence prove superior to others, it is not our object to have this fact used as an advertising feature by those manufacturers whose paints, when analyzed, show a like composition. Such a result would be entirely incidental to the test. We will not endeavor to antagonize or promote any commercial interest, but will simply give the results that are honestly obtained from the tests.

Frequent inspection trips have been made to both fences and a record is on file of the observations made on the various formulæ applied. It has been noticeable that the results from the first inspection differed materially from those of the second and third, showing that it would be entirely unjust and unsafe to issue a report at such an early period on the value of the different formulæ. For instance, a paint called A may have shown up as superior to B or C at the end of the second month's wear, while at the end of the fourth month B and C may have shown up as superior to A. Thus it is clear to see that it will be necessary for a much longer period to elapse before sending out a report regarding the value of one type over that of another.

However, some most interesting results are apparent, and, although they may have been predicted at the outstart in certain cases by paint technologists, they are at least substantiating the claims that the inert materials which some of the manufacturers are using are of value when used with moderation.

The severe conditions of climate affecting the cities wherein our fences are located have promoted and accelerated these tests to such a degree that, to a casual observer, a marked change is at once apparent. Disintegration of film, checking, chalking, poor hiding properties, and general lack of virtue, are the signs that are beginning to manifest themselves in certain instances. In other cases formulæ

Inspections

Results
Apparent

Steel
Test Fence

of a different type have shown up so well that it is extremely difficult to mark the slight changes that have been effected by wear.

In the letter sent out from the Section to the manufacturers on August 12th a general idea of this latest project of the Section was given, and the subject of rust inhibitive paints was touched upon. In this letter a description of the steel test fences was given. In order to bring this matter once again before the members of the Association a reprint of this letter will be found following my report. This subject is of great import to the manufacturer, and if he overlooks it the consequences he will suffer may be greater than at first thought may appear.

Protection with
Inhibitive
Pigments

The Government desires proper protection for its battle-ships, and the architect and engineer demand the same requirements for the enormous structural work under their care. Consequently, the wise purchasing agent insists upon the most valuable protective compound. He is largely guided by the engineers and technical men who are associated with him. These technical men, in turn, are studying the latest scientific developments that the Government authorities are promoting. If it is proven that certain compounds which have pigment values will prevent the corrosion of iron, the engineers will ask for paints containing these products, and if the manufacturer of paints shows a lack of interest or refuses to comply with their request, it is natural for these engineers to look to some other source for the solution of their problems.

The near future may show some wonderful achievements in the treatment of steel surfaces, either physically or chemically, giving the steel non-corroding properties. The metallurgist will give this question more attention than ever if the manufacturers are unable in the future to produce protective coatings that will guard the metal better than those which in the past have been so largely used. Consequently, if the manufacturers of protective compounds desire to maintain and increase the use and value of their products, it will be necessary for them to give more than a passing

thought to the value of the new inhibitive compounds that promise a new era in the manufacture of these paints.

The last meeting of Sub-committee E, American Society for Testing Materials, the Committee on Steel Fence Tests, was held in Washington on September 15th. A comparison of the results of the Laboratory investigations undertaken by the various members of the committee on the rust-inhibitive properties of paint pigments showed these tests to conform very closely to the results of Mr. Cushman, and the final selection of pigments for the test was made. The pigments are being ground at the present time, and the fences are already under construction at Atlantic City. Active work on the painting of the fences will be started some time this month.

Respectfully submitted,

H. A. GARDNER, *Assistant Director.*

TESTS UPON THE CORROSION OF IRON.

To be Conducted by the Scientific Section.

PHILADELPHIA, Aug. 11, 1908.

TO THE MEMBERS OF THE PAINT MANUFACTURERS' ASSOCIATION:

With the idea in view of giving to the members of the Association such information as will prove of practical value to them, and aid in stimulating business, the Section deems it advisable to call your attention to the subject of Rust-Preventative Paints.

This is a subject upon which you may have put considerable time and study in an endeavor to produce protective coatings that would withstand, to a certain extent, the action of the elements. The importance of recent discoveries and research work bearing directly upon this subject will be made clear to you by a brief description of this work which may cause you to start your own machinery working along similar lines.

Protective
Coatings

Heretofore, manufacturers have endeavored to produce paints which, when dry, would give films impervious to the agencies of decay. The void-filling properties of certain pigments aided in producing the non-porous film which they were aiming to produce, and certain well-known pigments came into large usage for paints of this character.

Recent investigations into the nature of pigments have revealed the fact that they may be divided into three groups and termed Rust-Inhibitives, Inerts or Rust-Stimulators. The nature of the pigment itself or the nature of the impurities contained within the pigment, are factors deciding the position of the pigment in one of the three groups or types above mentioned. It may be expected that the use of rust-inhibitive pigments in paints designed for the protection of steel surfaces, will give to such a paint very valuable properties. Further consideration of the subject will aid us in selecting the proper pigments for such a purpose.

According to the Electrolytic theory of corrosion as stated by Mr. A. S. Cushman, of the Agricultural Department of the United States Government, certain fundamental principles underlie the corrosion of iron. As he states them they are briefly as follows:

That when iron is in contact with water, there will be a transfer of electricity from the free hydrogen ions of the water to the iron ions of the iron, causing the solution and subsequent oxidation of the metal.

That the presence of impurities having a difference in potential to that of the iron in which they are contained, and the uneven distribution of such impurities, increases the amount of electrical action.

That certain compounds are of such a nature as to excite electrical action, and consequently, stimulate corrosion, while still other compounds are of such a nature as to inhibit or prevent corrosion.

To the class of compounds that inhibit corrosion belong bi-chromates of the alkaline earth metals, these salts being pre-eminent among such compounds. It has been found that salts of certain metals may be precipitated with the

chrome salts to produce pigments which afford protection for the steel surfaces to which they are applied.

The results of a series of investigations into the rust-preventative nature of these compounds demonstrated that it was not safe to state that the chromates, as a class, were rust-inhibitives. Quite the reverse is true of many of these products and their composition, method of preparation, and impurities are factors which influence, to a marked degree, their value as protective compounds. Aside from those chromates which prevent corrosion, we have those which act in an inert manner, also those in which any inhibitive value is overbalanced by the effect of impurities, showing a strong stimulating action in the rusting of metal.

Varied Nature
of Chromates

In order to carry out in a practical manner the tests started by Mr. Cushman, which were designed to ascertain the rust-inhibitive value of all pigments, the Scientific Section was commissioned by the Bureau of Promotion and Development of the Association to erect a fence having several hundred steel plates upon which to try out the value of the different pigments when contained in an oil medium.

Test Fence

The American Society for Testing Materials was informed of the work proposed by the Scientific Section and Committees E. and U. of the Society decided to co-operate in inspecting and supervising the tests, proper specifications to be drawn up by these Committees. The members of these Committees and the Scientific Section are conducting laboratory tests at the present time that will not only serve as a check upon the previous investigations, but will give information upon which to base the main field tests. The plates to be used for the tests are to be rolled from three kinds of metal—ordinary open hearth structural steel, ordinary Bessemer low carbon steel and pure Ingot iron. In this way we will secure data relating to the resistance to corrosion of certain metals, when tested out simultaneously with others. The steel plates will be painted in two ways. part of them will be scratch-brushed in the ordinary way before painting, thus following out the usual mode of painting structural steel, part of the plates will be pickled in sul-

Inspection
and
Supervision

Steel Plates
Tested

phuric acid in order to completely remove the scale and the plates will be subsequently washed with lime so that all traces of the acid will be neutralized.

The test will be conducted in a thoroughly systematic and practical manner, following out the methods employed during the tests already made at Atlantic City and Pittsburg. The Master Painters' Association will be asked to co-operate with us in the work and to give us the benefit of their practical experience in this line. Inspectors and painters, representing the Committees and the Sections, will be upon the ground throughout the work. The scope of the work at once appeals to all interested in the preservation of steel and iron surfaces and the production of suitable materials for their protection.

R. S. PERRY, *Director,*
Scientific Section.

Method of
Conducting
Test

Master

Painters'
Aid

LABORATORY REPORT OF THE SCIENTIFIC SECTION

PREFACE

The Scientific Section herewith presents a resume of the work undertaken in the Physical and Chemical Laboratories under the supervision and direction of Mr. R. S. Perry, by the Chemists to the Section, H. A. Gardner and R. Harman Ashley.

This work has been largely of a research nature and the great success with which it has been attended is due to the detailed investigations made of the various subjects under consideration and to the earnest effort and endeavor to advance a better and clearer knowledge of paint. An effort has been made to select subjects which would appeal to the manufacturer who would make his paint along scientific lines and whose discrimination in the use of paint materials is born of a definite knowledge of their qualities or defects. Just as an architect calculates the stress that will be placed upon the steel he uses in his building, in the same manner the up-to-date paint maker secures definite information regarding the serviceability and other qualities of the component parts of his paint before he places it upon the market. It has been with an idea of bringing before the members of the Association an outline for future reference and study along the same paths, that the Section places before you the following outline. The work is divided into several chapters with the following captions:

1. Laboratory Arrangement.
2. Preparation of Paint Films and Film Testing Machine.
3. Table of Results and Work now under Way.
4. Use of the Microscope.
5. Film Sectioning and Deductions to be Drawn Therefrom.



Chemical Laboratory at the Disposal of the Scientific Section

6. Polar Micro Examinations and Microphotographs.
7. Viscosity.
8. Visual and Actinic Opacity.
9. Can Standards.
10. Color Nomenclature and Vehicle Characteristics.
11. White Pigment Nomenclature and Table of White Pigment Characteristics.

CHAPTER I.

Laboratory Arrangement.

Although as a rule the location and complement of a modern paint laboratory are subject to certain economic conditions, and are factors beyond the control of the average manufacturing concern it is advisable to place at the disposal of the chemist as complete an outfit as possible. Proper ventilation, dust prevention, modern lighting and heating accessories, and the well-balanced distribution of apparatus are factors which facilitate the completion of the problems under investigation. The arrangement of the modern physical and chemical laboratories at the disposal of the Scientific Section may prove of interest to manufacturers and their chemists.

The physical laboratory room is about twenty feet long, twenty-five feet wide and fifteen feet high, with plastered walls painted with several coats of inside white. The room is made light by two large windows with steel frames preventing dust infiltration, three and a half feet wide by eight feet high, which are seldom opened, but proper ventilation is secured by the use of an electric exhaust fan, located at one end of the laboratory, which draws in air through a pipe coming through the wall at the other end and changes the air content of the room every six minutes. The electric exhaust fan at the end of the room also communicates with the adjoining laboratory, the door of which contains a ventilator. The suction of the draft from the physical laboratory creates a pressure in the adjoining room, which

Ventilation

operates the ventilator in the door. In this way both rooms are constantly furnished with a fresh supply of air.

Air
Filtration

In order that the air coming through shall be perfectly purified and free from dust, there is interposed in the pipe a fourteen-inch steel sieve with double ends finely perforated, the body of the sieve being filled with finely divided cotton and asbestos. The air coming through is perfectly free from dust and for this reason the interior of the room is easily kept clean. The air, as it leaves the pipe and enters the room, passes through an open-top zinc box which covers a radiator through which a continuous flow of hot water may be kept in the winter and a continuous flow of cold water in the summer, in order to secure the desired and constant temperature throughout the year. As an accessory a series of grids are placed within the chamber in the air inlet, between the filter and the entrance to the laboratory. Upon these grids cakes of ice may be placed in order to assist in rapidly cooling the temperature of the laboratories.

Temperature
Control

The floor of the room is tiled, with a slight pitch to the centre, where a drain pipe takes off the water used to flush the floor in cleaning the laboratory. Clusters of electric lights are arranged in proper positions on the ceiling, on the walls and over the work tables. The entire length of the side containing the windows has a bench about four feet from the floor. This bench is supported on brass pipes, and the top of the bench is tiled and arranged for physical work, openings being made for the entrance of water, gas and air pipes. Drawers and cabinets are found under the bench within reach of the operator, so that easy access may be had to instruments and apparatus. At the opposite side of the room there stands a similar bench fitted up like the other, but used as a support for the various cabinets in which the films and film testing apparatus are kept. At the end of this bench is a very carefully made glass case wherein the more expensive glassware, platinum, &c., is kept. The farther side of the room contains other tiled tables for setting up apparatus such as viscometers, &c., and

Arrangement



A Corner of the Physical Testing Laboratories of the Scientific Section

in the corner sets a three-foot porcelain sink with hot and cold water. In the middle of the room is an enamelled iron-frame table, with glass top, very similar to a surgeon's table, and this is used for very fine work requiring great cleanliness. The various pieces of apparatus, such as film testing machines, camera stands for making microphotographs, microscopes and microscopic attachments, are found in their respective places.

Dark Room

Adjoining this room is a smaller physical laboratory room, arranged in such a way that it can be easily converted into a dark room for photographic purposes, having the necessary blinds, screens, ruby lights, &c. This room also contains tables, sinks, shelves, &c., and is tiled throughout and painted white like the adjoining room.

Chemical Laboratory

The laboratory where the chemical work is performed adjoins the physical testing laboratory. Many uses of the electric current are made in this laboratory, as, for instance; hot plates, grinding apparatus, ventilating fans, electrolytic analyses, centrifuges and lantern work. High water pressure also provides ample and modern service for rapid filtration, the drying ovens, water stills, water baths, sink fittings, &c. Sensitive analytical balances, together with balances for coarser weighings, are placed in a separate balance room boxed in from the main laboratory. The usual appurtenances and apparatus together with a good assortment of glassware and porcelain are at hand. A large number of carefully selected reagents are constantly on hand, together with stock solutions for volumetric work. These reagents are all properly marked and assigned to their respective places on shelves convenient to use.

Water Pressure

Balances

Apparatus

Reagents

Library

The members of this Association are, without doubt, familiar with the extensive library this section has gotten together for its work, and, through subscriptions, for the use of each member of the Association.

We herewith append a list of the books which we now have in our library:

LIST OF BOOKS.

- Petroleum and its Products. 2 Vols. *Sir Boverton Redwood*
 A Treatise on its Distribution, Occurrence, Physical
 and Chemical Properties, Refining and Uses.
- Handbook on Petroleum. *Thomas Redwood*
 A Treatise on the Industrial Use of its Products.
- Simple Methods for Testing Painters' Materials. *Wright*
- Letters to a Painter. *Prof. Oswald*
 On the Theory and Practice of Painting.
- Iron Corrosion and Anti-Corrosive Paints. *Andes*
- Dictionary of Chemicals and Raw Products. *Hurst*
 Used in the Manufacture of Paints, Colors, Varnishes
 and Allied Preparations.
- Oil Colors and Printers' Inks. *Andes*
 A Practical Handbook Treating of Linseed Oil, Boiled
 Oil, Paints, Artists' Colors, Lamp Black and
 Printers' Inks.
- Manufacture of Mineral and Lake Pigments. *Bersch*
 Containing Directions for the Manufacture of all Arti-
 ficial Artists' and Painters' Colors, Enamel Colors,
 Soot and Metallic Pigments.
- Chemistry of Paints and Painting. *Church*
- Painters' Laboratory Guide. *Hurst*
 A Handbook of Paints, Colors and Varnishes.
- Manufacture of Varnishes, Oil Crushing, Refining,
 etc. *Livache*
- Pigments, Paints and Painting. *Terry*
 A Practical Book for Practical Men.
- Rustless Coatings, Corrosion and Electrolysis of Iron
 and Steel. *Wood*
- Mixed Paints, Color Pigments and Varnishes.
Holley and Ladd
- Chemical Technology and Analysis of Oils, Fats and
 Waxes. Vols. 1 and 2. *Lewkowitsch*
- Chemistry and Technology of Mixed Paints. *Toch*
- Chemistry of Paint and Paint Vehicles. *Hall*

- Testing and Valuation of Raw Materials Used in
 Paint and Color Manufacture.....*M. W. Jones*
 Painters' Colors, Oils and Varnishes. 2 Vols...*G. H. Hurst*
 The Manufacture of Varnishes and Kindred Indus-
 tries. 2 Vols.....*Livache and McIntosh*
 The Manufacture of Lake Pigments from Artificial
 Colors.....*F. H. Jennison*
 Drying Oils, Boiled Oil and Solid and Liquid Driers
L. E. Andes
 A Practical Work for Manufacturers of Paints,
 Oils, Varnishes, etc.
 Students' Handbook of Paints, Colors, Oils and Var-
 nishes*John Furnell*
 Manufacture of Paint.....*J. Cruikshank Smith*
 A Practical Handbook for Paint Manufacturers.
 The Chemistry of Pigments.....*E. J. Parry*
 House Decorating and Painting.....*W. Norman Brown*
 A History of Decorative Art.....*W. Norman Brown*
 Notes on Lead Ores.....*Jos. Fairie*
 Their Distribution and Properties.
 Technology of Paint and Varnish.....*Sabin*
 Oil Chemists' Handbook.....*Hopkins*
 Proceedings of the American Society for Testing
 Materials—10th Annual Meeting.
 Chemiker-Kalendar. 2 Vols.
 Principles of Reinforced Concrete Construction
Turneaure and Maurer
 Mechanical Engineers' Handbook.....*Kent*
 Outlines of Inorganic Chemistry.....*Gooch and Walker*
 Table of Minerals.....*Samuel Lewis Penfield*
 Including the Uses of Minerals and Statistics of
 the Domestic Production.
 Food Inspection and Analysis.....*Leach*
 Enzymes and their Applications.....*Effront-Prescott*
 Determinative Mineralogy and Blowpipe Analysis
Brush-Penfield
 Physics*Ganot*

Analytical Chemistry (Qualitative Analysis). Vols.	
1 and 2.....	<i>Treadwell Hall</i>
Quantitative Chemical Analysis by Electrolysis	
	<i>Classen Boltwood</i>
Text-Book of Chemical Arithmetic.....	<i>Wells</i>
Elements of Physical Chemistry.....	<i>Morgan</i>
Manual of Quantitative Chemical Analysis.....	<i>Ladd</i>
Techno-Chemical Analysis.....	<i>Lunge-Cohn</i>
Tests and Re-Agents, Chemical and Microscopical....	<i>Cohn</i>
Spectrum Analysis.....	<i>Laudauer-Tingle</i>
Microscopy of Technical Products.....	<i>Hanausek Winton</i>
Manipulation of the Microscope.....	<i>Edward Bausch</i>
Micro-Chemical Analysis.....	<i>Behrens</i>
Pamphlets:	
Electrolytic Theory of Rusting.....	<i>A. S. Cushman</i>
Corrosion of Fence Wire.....	<i>A. S. Cushman</i>
Some Technical Methods of Testing Miscellaneous	
Supplies.....	<i>P. H. Walker</i>

CHAPTER II.

Preparation of Paint Films and Film Testing Machines.

Up to the present time the experimentation which has been done upon paints has been a practical trying out in the way of field tests. The examination and investigation into the nature of the isolated paint has often been attempted, though with but slight success up to the present time.

1. The preparation of paint films. Among the many methods which have been suggested and attempted for securing paint films, we may mention a few already fairly well known.

By painting upon zinc and eating away the zinc with acid. The objection to this method is very evident, namely, the action of the acid upon the paint coating, which is likely

No. 1
Preparation
of Films

to be very severe. Another method has been to spread paraffine on a glass plate and painting upon this surface. When the paint is dried, the paraffine is melted off and thus the film is obtained. This method also is open to objections, in that the paraffine surface is not a comparable one upon which to paint, and also that the complete removal of the paraffine is not assured.

Another method consists in covering a piece of glass with tin foil, painting out the film upon the foil, and after drying properly to remove the sheet of foil with its coating of paint and immerse in a bath of mercury which by amalgamation of the tin leaves the paint film.

We now come to a method worked out in the section laboratories, which can be recommended as being not only simple but efficient and practical. It has been found that a size from noodle glue when painted upon ordinary fair quality paper makes a surface from which the paint may be subsequently stripped. The paint is applied in the ordinary way to the paper, which is held during the operation by thumb tacks, and allowed to dry. The paint may be separated by immersion in water kept at about 50 degrees C. By this method large films may be obtained, but it has been found very unhandy to work with films exceeding an area of eight inches square. When the film of paint has been detached from the sized paper through the dissolving of the noodle glue, the paint film is then immersed in a fresh solution of water, in order to remove whatever excess of noodle glue there may be remaining. A glass rod is then introduced into the bath, in which the paint film is floated upon the glass rod, which is then hung up to dry in a suitable container to prevent the accumulation of dust, etc.

2. The film being prepared as in the above it is now desirable that proper use should be made of it and that proper machines should be set up for the testing and measuring of the qualities of the isolated paint film.

A film testing apparatus, which has been termed a Filmometer by its originator, Mr. R. S. Perry, has been constructed, with the following features: A graduated upright

tube is fixed by means of sealing wax to two metallic plates which carry an evenly bored hole, exactly under the hole in the upright tube. This hole measures exactly one square centimeter in area, and is circular. The upright tube is graduated into lineal centimeters and is called the pressure tube.

Attached to the lower end of this pressure tube, close to the metallic plates, which serve as carriers for the paint film to be tested, is a side-neck, which is inclined at an angle of 45 degrees to the pressure tube, and serves the purpose of introducing the mercury, as will be described later. Immediately under the openings in the metallic plates which carry the film are arranged two pieces of iron inclined at a 90 degree angle, so arranged that when the pressure of mercury is applied and causes rupture of the film the falling mercury shall be caught between these two insulated plates and cause contact. These two plates are connected up by wire with a pair of magnets, thence to an electric bell, and from there to storage batteries which supply the current.



Film Testing Machine

A film of paint is tested in the following manner: A piece of film one inch square is cut out and placed between the two metallic plates which hold the film immediately under the pressure tube. Mercury is run in from a burette through the side-neck and applies pressure upon the film by gravity. As the mercury is run in it rises of course in the tubes until this pressure becomes so great as to finally break the film. At this point the mercury will run out, and, falling upon the two insulated iron plates immediately below, will cause contact and close the circuit which rings an electric bell, which is a signal for the operator to shut off the inflow of mercury through the side-neck from the burette.

The pressure tube is also supplied with a piston which is made of a piece of thin iron wire having a disc attached to its lower end. As the mercury rises in the pressure tube this iron wire is pushed up, being very delicately counterpoised over a wheel. Upon the breaking of the film, the mercury runs out, but upon falling upon the two iron plates underneath causes contact to be made, which causes the current to run through the pair of magnets before mentioned, which, becoming electrified, attract the piston in the pressure tube, giving a reading for the maximum height of the column of mercury.

The supply of mercury being shut off, we are now in a position to determine the total sum of both the elasticity and ductility of the paint film, and also the pressure at which the film broke. The breaking pressure of course is read directly upon the pressure column, which is divided into centimeters as has been described above, the piston of course indicating the maximum height of the mercury column. We are now in a position to calculate what may be termed the elasticity of the film. As is perfectly evident the film in stretching does so by distending from a flat surface to a curved or cup-like surface. If we have our pressure tube calibrated in cubic centimeters reckoned from a flat surface where the film was introduced we are in a position to determine the stretch of the paint film in stretch-

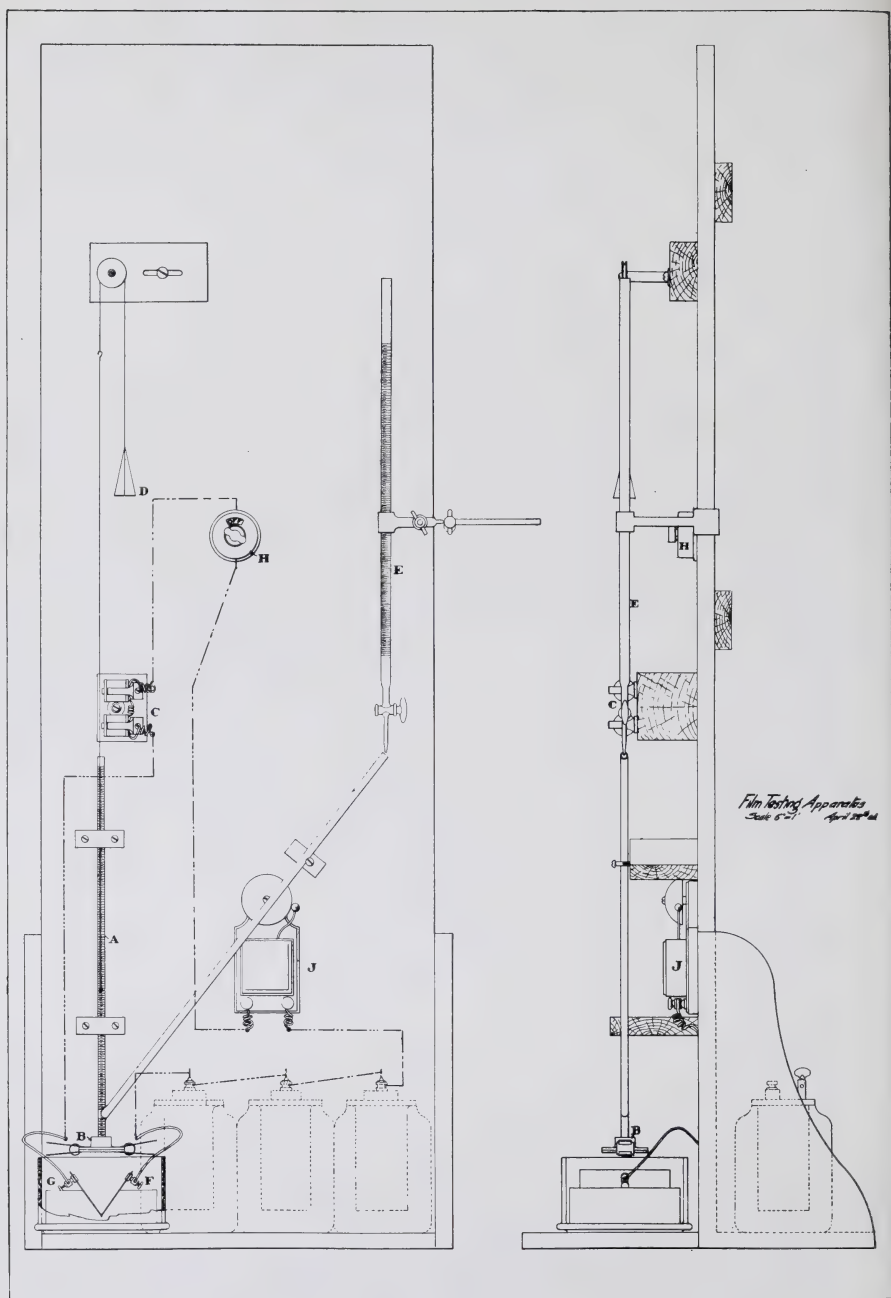


Diagram of Perry Filmometer

ing from a flat surface to a curved surface. The cubic contents of the pressure tube and side-arm become increased owing to the cup-like shape the paint film takes on. By subtracting the amount of mercury indicated by the piston in the pressure tube from the amount of mercury delivered from the burette the difference is the amount of mercury contained in the distended paint film, which serves as a measure of its elasticity.

The temperature is a most important point to consider in running daily tests upon the filometer. The tests made in the Section Laboratories were conducted at 70 degrees F. throughout.

The Scientific Section has on hand a limited number of film testing machines, and will supply them at almost cost to any member of the Association.

CHAPTER III.

Table of Film Testing Results and Work Now Under Way.

By means of the film testing apparatus described in the above, interesting results have been obtained, which are embodied in the following table:

Comparative Strengths of Films as Obtained by the Breaking Machine.

		No Coats.	Pressure.	Thickness.	Stretch.
1.	Zinc Oxide.....	3	33.2	0028	.30
2.	Zinc Lead.....	3	32.7	0034	.35
3.	Asbestine	3	28.0	0045	.15
4.	Pitcher Lead.....	3	17.9	0024	.38
5.	Barytes	3	13.3	0042	.33
6.	Beckton	3	13.1	0024	.49
7.	Whiting	3	13.0	0033	.32
8.	Quick Lead.....	3	11.3	0025	.38
9.	Gypsum	3	10.8	0039	.29
10.	China Clay.....	3	10.8	0035	.16
11.	Silex	3	9.6	0032	.32
12.	Blanc Fixe.....	3	8.5	0030	.28
13.	Dutch Lead.....	3	7.3	0020	.33
14.	Ba Carb.....	3	7.2	0028	.16

By means of this machine we expect to be able to obtain very valuable information concerning the effect of age upon a paint as influencing its strength and elasticity. These are two vital qualities in a paint, as it is through its strength that a paint resists abrasion, cracking, peeling and blistering. That elasticity is a vital qualification of a paint may easily be seen through the checking of oil paintings, which, as Ostwalt has pointed out, is due to the unequal co-efficients of expansion between the ground and the paint. This is

particularly noticeable in the alligating of many enamels which contain large percentages of zinc. The Scientific Section has a large collection of films which are being tried out periodically and curves have been obtained, showing the influence of time upon the elasticity and the strength of paint films.

Curves have also been prepared having pressure as an abscissa and elasticity as ordinate. These curves show remarkable differences in different pigments. For instance, in the case of white lead, the curve takes a steep upward trend when it apparently reaches a maximum, the curve then flattening out and finally taking another steep upward trend just before breaking. This may be construed as follows: That under low pressures the white lead film is perfectly elastic, when a maximum is obtained, beyond which elasticity does not extend. This point is the maximum point of the upward trend. From here on pressure may be applied without any increase in stretch, this being represented by the flat part of the curve, while the steep upward trend just before breaking shows where the paint begins to tear, finally culminating in breaking. In the case of asbestine, however, the curve is more of a straight line up to the breaking point, which would go to prove that elasticity is proportionate to pressure in the case of this pigment.

CHAPTER IV.

Use of the Microscope.

Use of the Microscope

4. The microscope is a necessary adjunct of every well-ordered paint laboratory, as has been recognized throughout the whole paint industry, and the Scientific Section has attempted to collect certain data which may materially assist those manufacturers who employ this instrument to judge of the quality of their raw and finished products. The fineness of grinding considerably affects the quality of the paint, and this can be easily controlled through the intelligent use of the microscope. This instrument may also be used to detect certain adulterations. Appended is a table giving the fineness of grinding of the various pigments, together with their characteristics under the microscope. In this table measurements are given both in millimeters and in inches, in order to accommodate itself to the use of those chemists employing a millimeter stage micrometer, or those employing the English or inch system. Although it is not yet certain that any and all combinations of pigments may be detected under the microscope, yet the Scientific Section is working toward a method which will allow a manipulator to judge of the composition of the paint under observation.

In order to properly prepare a paint for microscopic examination, the following method is recommended: A microscopic turn table is a convenient accessory of the microscope, and its use is to be recommended. A glass slide being placed in position upon the turn table, a very small amount of either the pigment rubbed up in oil, or the paint, is applied to the slide; a small drop of Canada balsam is then applied by means of a glass rod dipped in the solution of balsam in xylol, and dropped upon the slide. The rod is then used to thoroughly incorporate the pigment with the balsam, and a cleaned cover glass is dropped over the

whole and pressed down tightly, so that a small amount of balsam will exude from under the edges and thus firmly seal the glass. In order to make permanent slides it has been found advisable to rim the cover glass with balsam and even follow this up with some suitable black varnish, the slide being then carefully labeled and placed in the collection. Following is a table of the characteristics of the fourteen chief pigments:

**TABLE OF THE SIZE OF PARTICLES OF THE CHIEF
PIGMENTS WITH THEIR CHARACTERISTICS UNDER THE MICRO-
SCOPE.**

No.	Name	Diameter in Millimeters			Diameter in Inches		
		Small	Average	Large	Small	Average	Large
1.	Asbestine.....	.002		.12	.00015		.049
2.	China Clay.....	.003		.065	.00009		.025
3.	Barium Carbonate.....	.00076—	.0055	.0172	.00003	.00024	.0011
4.	Blanc Fixe.....	.00073	.0037	.0073	.00003	.00014	.0003
5.	Silex.....	.0037	.0092	.03	.00014	.00036	.0012
6.	Gypsum.....	.0037	.011	.05	.00014	.00044	.0022
7.	Amer.-Paris White.....	.0015	.0050	.04	.00006	.00022	.0018
8.	Barytes.....	.0015	.0092	.05	.00006	.00036	.0021
9.	Zinc Lead.....	.00037	.0018	.0037	.000014	.00007	.00014
10.	Picher Lead.....	.00037	.0018	.0037	.000014	.00007	.00014
11.	Beckton.....	.00076	.0018		.00003	.00007	
12.	Zinc Oxide.....	.00046	.0018	.00037	.00002	.00007	.00014
13.	Quick Pro. Lead.....	.00061	.0030	.0048	.00002	.00012	.00018
14.	Dutch Pro. Lead.....	.00061	.0018	.0066	.00002	.00007	.00026

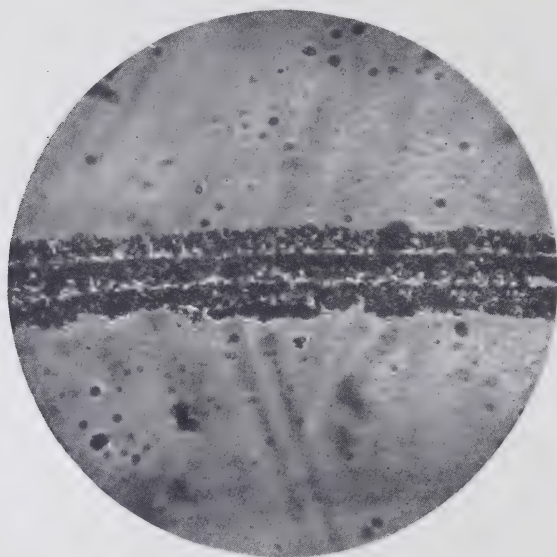
REMARKS.

- (1) In rectangular crystals and rods.
- (2) In flat plates.
- (3) Dotted round particles.
- (4) Non-crystalline. Very uniform.
- (5) Transparent. Not characteristic.
- (6) Very transparent. In plates.
- (7) Very transparent. In plates.
- (8) Clean-cut, sharp crystals.
- (9) Non-crystalline. Uniform.
- (10) Non-crystalline. Uniform.
- (11) Non-crystalline. Uniform.
- (12) Non-crystalline. Uniform.

CHAPTER V.

Film Sectioning and Deductions to Be Drawn Therefrom.

5. Investigations were undertaken into the innermost structure of paint films as revealed under the microscope. Up to the present time, work has been done upon Barytes, Asbestine, Blanc Fixe, White Lead and Inside White upon wood and Outside White upon wood. The films, the preparation of which has been described in the foregoing, were sectioned and prepared for microscopic examination in the following manner:



Section Barytes Film

A solidifying dish was partly filled with low melting point paraffine and the same allowed to harden, when a small piece of paint film was thrown upon it and then more paraf-

fine poured over it. After hardening, sections were obtained of the paint film by means of a microtome.

These sections of paint films under the microscope gave an idea as to the innermost structure of a paint such as had not been afforded heretofore. It was easy to perceive the relative position of the pigment particles and the three coats. The penetration of one coat into another was easily discernible, and measurements were made upon the sections in order to determine the average thickness of coat and general appearance of the same.

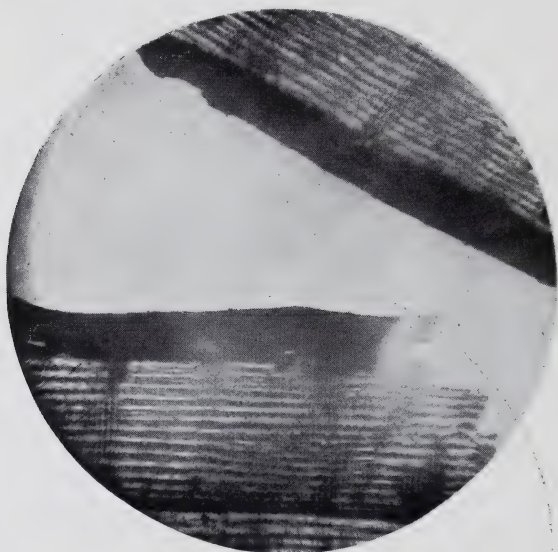
Film
Sectioning
and
Deductions
to be Drawn
Therefrom



Outside White on Wood

Sections were also made of Inside and Outside White upon wood. These sections revealed under the microscope the thickness of the coats and also the penetration of the priming coat into the wood. Appended is a table giving microscopic measurements. This work is under way and is

not complete, but when amplified will give valuable data, in support of the strengthening and void-filling properties of the re-enforcing pigments.



Inside White on White Pine

Pigment

Paint Section Measurements Under Microscope.

		<i>Millimeters.</i>	<i>Inches.</i>
Barytes	3 coats (sum) ..	.1068	.00421
	Single coat.....	.0356	.00140
Inside White on Wood Field in Photographs	3 coats (sum) ..	.1624	.00639
	Outside coat....	.0230	.00091
	Next coat.....	.0443	.00175
	“ “ .....	.0620	.00245
	Penetration ....	.0294	.00116

Inside . . . . .	.0215	.00085		White Lead
Middle . . . . .	.0405	.00159		
Outside . . . . .	.0184	.00073		
3 coats (sum) ..	.0811	.00319		
3 coats (sum) ..	.1840	.00725	Not very uniform. Hard to get single coat.	Asbestine
3 coats (sum) ..	.1068	.0042	Very uniform. Each	Blanc Fixe
Single coat . . .	.0356	.00014	coat very even.	
Outside coat . . .	.1329	.00523		Outside
Inside " . . .	.1845	.00727		White
Penetration . . .	.0737	.00290		on Wood

CHAPTER VI.

Polar—Micro—Examinations and Micro-photographs.

6. By Polar Micro Examination is meant the examination of pigments under polarized light. A polarizing apparatus, though not an essential in the hands of the paint chemist, is nevertheless much to be desired, for by its help deductions may be drawn as to the contents of a paint, which by other means might not be possible. The polarizing apparatus as marketed by most manufacturers of the microscope is attached in the following manner :

Polar
Micro
Examination

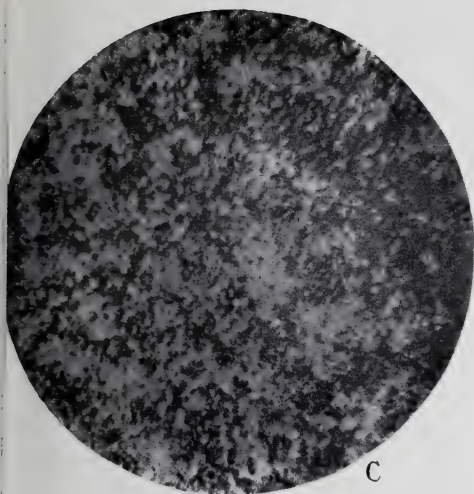
The diaphragm immediately under the sub-stage container is swung out and opened to its widest limit, allowing the insertion of the polarizer. This polarizer carries one of the pair of Nicols prisms and is countersunk to allow of the introduction of gypsum or selenite plates. The analyzer fits over the eye-piece on the tube.

The use of polarized light upon paint is valuable on account of its action upon crystalline substances. The reinforcing pigments, such as Asbestine, China Clay, Gypsum, Silex, Barytes, etc., are crystalline and consequently act upon the polarized light. In most cases these pigments are used in ready-mixed paints in small amounts, varying be-

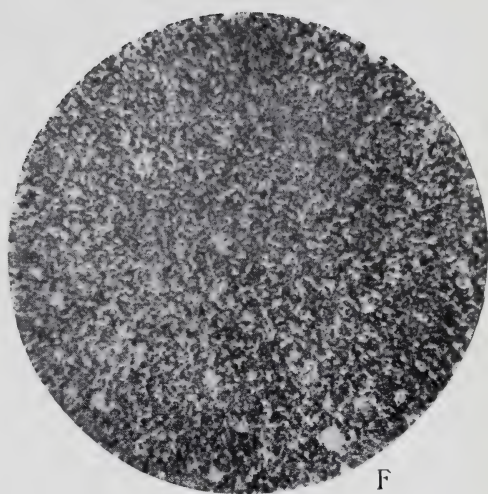
tween 5 and 25 per cent. When a slide containing a small amount—for example, less than 3 per cent.—of these crystalline pigments is examined under the microscope by ordinary transmitted light, they will often escape observation, owing to the small amount in which they are present. However, in the case of polarized light, this could hardly happen.

A slide of paint containing these re-enforcing pigments is prepared in the usual manner. On examining this under the microscope and using the polarizing apparatus, the crystalline pigments are at once detected by revolving the analyzer. At one position of the analyzer, one sees an ordinary field, as with transmitted light, but if one revolves the analyzer, the field gradually becomes darker until total darkness is obtained throughout, except in such places where crystalline substances are present, when the crystal is shown up with beautiful distinctness.

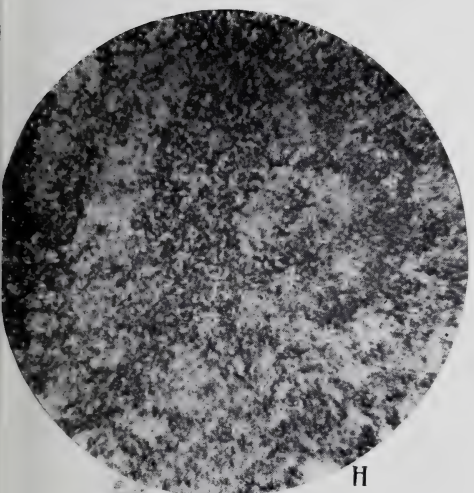
7. The preparation of micro photographs is of interest and value to the paint trade, as may be evidenced by many of the excellent works which have been written upon this subject in connection with paint within recent date. Micro photography and micro chemical analysis is coming more and more to the front, and by its means and with its help, the Scientific Section hopes to accumulate and prepare a set of micro photographs which will be of value to those manufacturers having a microscopic outfit, as by their means the characteristic appearance of certain pigments may be kept for reference.



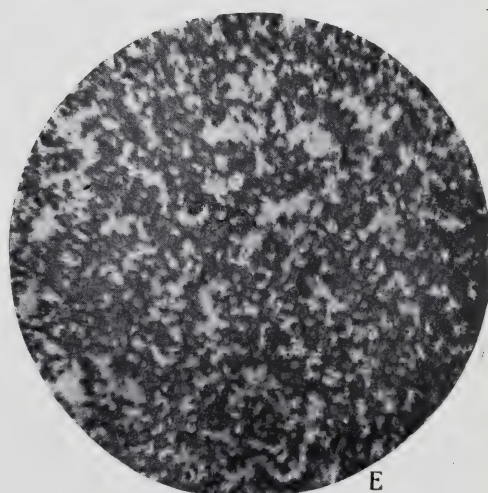
C White Lead



F Zinc Oxide

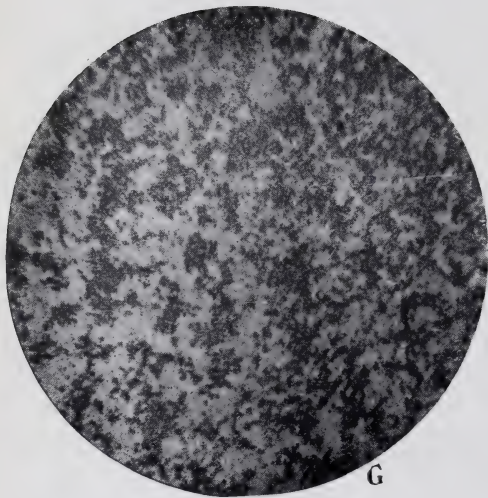


H Sublimed White Lead



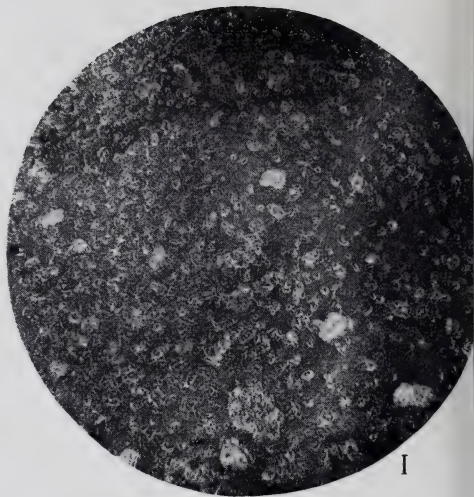
E Lithopone

MICRO-PHOTOGRAPHS OF PROMINENT PAINT
PIGMENTS. MAGNIFICATION 250 DIAMETERS.



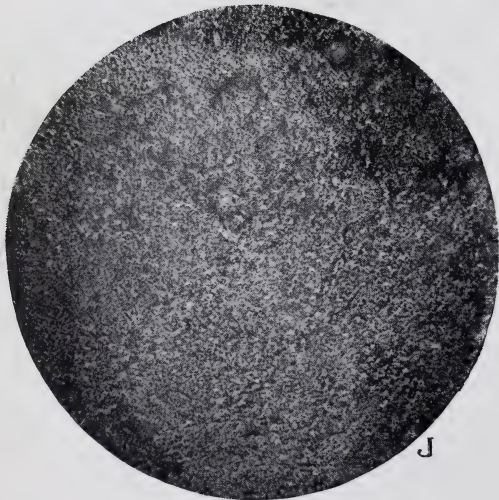
G

G Zinc Lead White



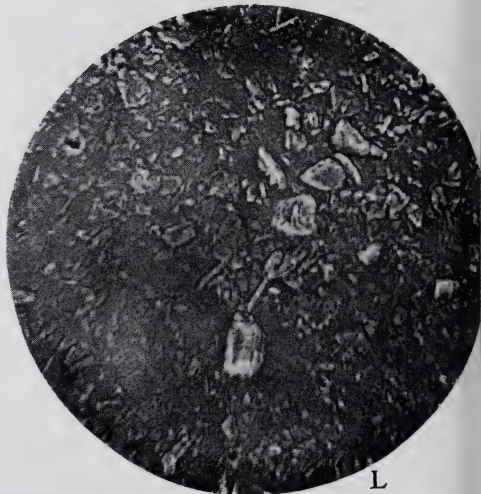
I

I Calcium Carbonate



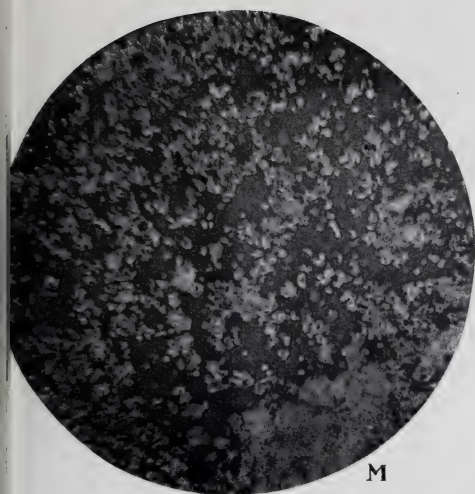
J

J Blanc Fixe



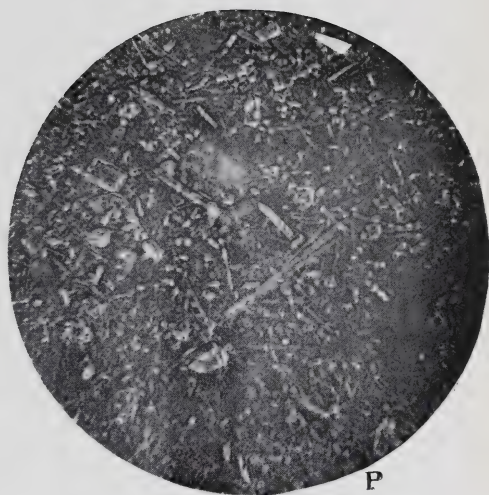
L

L Sillex



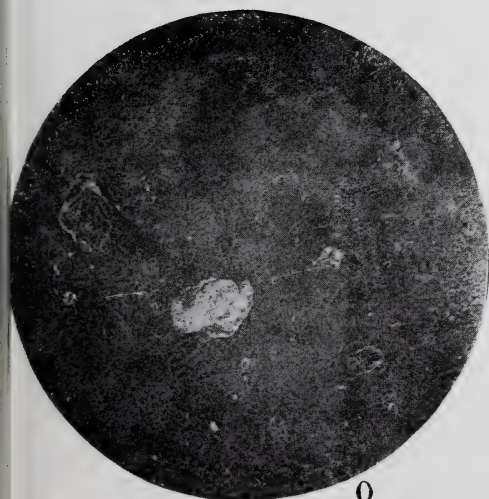
M

M Barytes



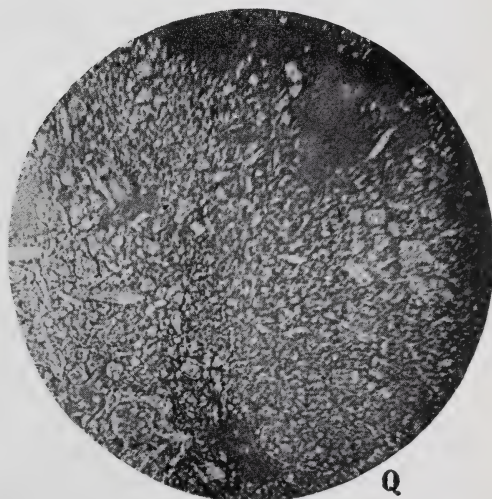
P

P Asbestine



O

O Calcium Sulfate



Q

Q China Clay

CHAPTER VII.

VISCOSITY.

The viscosity of paint is an important subject, as this bears a close relation to the flow of the paint under the brush. The viscometers in ordinary use depend upon the principle of having a regulated amount of liquid flowing through a standard orifice. Below is a table of the viscosities of paints consisting of 50 per cent. pigment and 50 per cent. oil, obtained by the Reilly viscometer. This viscometer is used in testing oils, etc., and in using this instrument the conditions imposed by the manufacturer of the instrument were closely adhered to. Attempts were made to determine the relative viscosities of ready-mixed paints with this apparatus, but without success, as the employment of this machine calls for a temperature of 210 degrees, at which temperature a paint considerably changes its physical characteristics.

Reilly
Viscometer

VISCOSITIES OBTAINED BY THE REILLY VISCOMETER.

<i>Name.</i>	<i>Time of Flow.</i>	
Asbestine	14'	25"
China Clay	3'	48"
Ba Carb	1'	4"
Blanc Fixe	7'	45"
Silex	1'	51"
Gypsum	2'	6"
Whiting	3'	10"
Barytes	0'	48"

Zinc Lead	1'	7"
Picher Lead	1'	2"
Beckton	2'	17"
Am. Zinc	5'	13"
Quick Pro. Lead.....	0'	48"
Dutch " "	0'	53"

9. In seeking an apparatus which would give the viscosities of paints, the Doolittle torsion viscometer was found to be the most reliable and scientific instrument. This instrument has previously been applied to varnishes, but never before has it been successfully used with paints. The principle of this viscometer may be roughly sketched as follows:

To the end of a wire about twenty-one inches long is suspended a standard cylinder. The wire also carries a disc marked in degrees. The metallic cylinder is immersed in the oil or other substance, the viscosity of which is to be measured. The cup carrying the liquid is surrounded by a water jacket in order to carefully regulate the temperature. Viscosity is measured by giving the wire one complete turn of rotating it through an angle of 360 degrees, the cylinder being free to swing or twist, owing to the torsion exerted upon the wire. According to the viscosity of the liquid so will the rotation of the cylinder be retarded; in fact, the laws of the pendulum apply in this case. By obtaining readings upon the graduated disc, the viscosities of the paints are obtained, which are relative and are given in the following table:

**Doolittle
Viscometer**

VISCOSITIES TAKEN ON THE DOOLITTLE VIS-
COMETER AT 80 DEGREES F, USING
 $\frac{1}{2}$ -IN. CYLINDER.

No.	5	Silex	30.3	degrees
"	3	Barium Carb	30.7	"
"	9	Zinc Lead	32.5	"
"	8	Barytes	50.2	"
"	6	Gypsum	56.4	"
"	7	Whiting	64.9	"
"	2	China Clay	78.4	"
"	14	Dutch Pro. Lead	101.5	"
"	4	Blanc Fixe	102.5	"
"	1	Asbestine	112.8	"
"	13	Quick Pro. Lead	119.3	"
"	12	Am. Zinc	153.6	"
"	11	Beckton	176.5	"
"	10	Picher Lead	213.7	"

The Scientific Section has under way a set of experiments to determine the relation of percentage of pigment in the vehicle to the viscosity of the mixture. These experiments have not been completed, but seem to point to the fact that there is a close relation between the oil absorption values of a pigment and its viscosity. This work will be completed at a very early date.

CHAPTER VIII.

VISUAL AND ACTINIC OPACITY.

Upon this field of paint research, little as yet has been done, as its successful performance is beset by so many difficulties.

By visual opacity is meant the amount of light excluded so far as this may be measured by the eye. In its relation to paints it is of importance, as it concerns the hiding or obscuring power of a paint or pigment. Visual opacity bears no direct relation to the sealing quality of a paint and is totally concerned with its decorative use.

Visual and
Actinic
Opacity

Experiments upon the visual opacity of paints were carried out in the following manner: A carefully cleaned piece of glass was first accurately measured for thickness with the greatest degree of precision possible. Upon this measured piece of glass the master painter spread a coat of paint employing a camel's hair brush and endeavoring to apply the coat as uniformly as possible. After the hardening of the paint, the glass was again measured for thickness at certain marked points, and by this means the thickness of the film of paint was obtained. The method of measuring the visual opacity of the paints is as follows: A mark is made upon the other side of the glass from the paint, and pieces of onion paper are added in layers and pressed close against the glass until the mark could no longer be perceived. Assuming the pieces of onion paper are uniform in their light obscuring powers, the greater the number of pieces of paper used, the less the visual opacity of the paint coating.

As is perfectly evident it is well to have as bright a light as possible behind the slide, as this will entail the use of a larger number of pieces of paper, and consequently, smaller percentage error of experiment. Account must be

taken of the thickness of the film and a correction made to make the values obtained comparative.

By actinic opacity is meant the ability of a pigment to exclude actinic or chemically active rays. Chemical action is generally accelerated by light, though we may have actinic rays in the absence of light which is perceivable by the eye. A common example of the action of the actinic light is the photographs prepared from radio-active substances, which to the naked eye appear non-luminous, though possessing the power of emitting actinic rays which set up chemical action in a photographic plate. This matter is of great importance as affecting the protective value of a paint, as it is largely through the agency of actinic light that chemical decomposition is brought about. The method employed to measure the actinic opacity of the various pigments was as follows:

The same painted glass slides used in obtaining the visual opacity were again employed to measure the actinic opacity. As is well known, Velox paper is acted upon by the actinic rays. The glass slides are placed in a printing frame with the film side in, and upon this was placed Velox paper and the frame closed as in ordinary negative printing. The frame is placed at a uniform distance from the light and the exposure timed, so that the prints on developing the same length of time in the developing bath shall all give the same tone, the time of exposure being used as a measure of the actinic opacity of the film. Appended is a table giving the visual and actinic opacity of the chief pigments:

TABLE OF ACTINIC OPACITY.

No. 1.....	Zinc Oxide	100%
No. 9.....	Zinc Lead	100%
No. 10.....	Picher Lead	67%
No. 11.....	Beckton	67%
No. 13.....	Quick Process Lead.....	23%
No. 14.....	Dutch “ “	17%
No. 3.....	Barium Carbonate	4%

No. 7.....	Whiting	4%
No. 8.....	Barytes	4%
No. 4.....	Blanc Fixe	4%
No. 2.....	China Clay	2%
No. 1.....	Asbestine	2%
No. 5.....	Silex	2%
No. 6.....	Gypsum	2%

TABLE OF VISUAL OPACITY.

No. 9.....	Zinc Lead	100%
No. 12.....	Zinc Oxide	100%
No. 11.....	Beckton	91.7%
No. 13.....	Quick Process Lead	91.7%
No. 10.....	Picher Lead	87.5%
No. 14.....	Dutch Process Lead	87.5%
No. 3.....	Barium Carbonate	75.0%
No. 7.....	Paris White	70.8%
No. 1.....	Asbestine	66.6%
No. 4.....	Blanc Fixe	58.3%
No. 5.....	Silex	45.8%
No. 8.....	Barytes	41.6%
No. 2.....	China Clay	25.0%
No. 6.....	Gypsum	4.2%

This laboratory expects to be in a position to issue a supplementary pamphlet in the near future, which will embody many features which are beyond the scope of the present issue, such as the micro-photographs by means of polarized light of the various pigments, micro-photographs of film sections showing the arrangement of the pigments in the paint, micro-photographs of paint upon wood, showing the penetration of the priming coat, and also a fuller account of the film testing apparatus and various curves obtainable by the same, showing the progressive oxidation or ageing of paint films, and curves showing the relations between pressure and stretch.

CHAPTER IX.

CAN STANDARDS.

Work on Can
Standards

11. This laboratory has also undertaken investigations into the sizes of cans found upon the market throughout the country. It was found that the prevailing opinion of manufacturers and users of cans was that approximately 5 per cent. air space should be present between the top of the can and the paint, such air space giving an air cushion for the expansion and contraction of the paint, as all manufacturers are fully aware it is impracticable to fill the can full before sealing. The method of procedure in standardizing cans was essentially as follows:

The cans were first counterpoised upon a balance and water poured in and the volume of water was then determined by weighing and converting this to volume by the necessary calculations.

We have secured hundreds of samples of cans from different manufacturers throughout the country, and we have calibrated these cans, and placed upon our files an immense amount of data on this subject. As a result of this work, we have decided on a series of cans in the proper sizes, and herewith recommend this list to the Association for universal use. The cans indicated in this list are of such a size that they will contain full United States measure, and, at the same time, have the necessary air space after the proper volume of liquid has been placed in the can. In order to arrive at conclusions regarding the proper air space necessary in cans, different sizes containing paint were obtained from several cities, and upon investigation it was found that 75 per cent. of the manufacturers favored $\frac{1}{2}$ -inch air space for gallon and half gallon cans, and $\frac{3}{8}$ -inch for quarter gallon and eighth gallon cans.

CAN SIZES RECOMMENDED TO THE PAINT MANUFACTURERS' ASSOCIATION BY THE SCIENTIFIC SECTION.

(In some cases, optional sizes are given holding
the same volume.)

Hole and Cap	Friction Top	Open Top or Double Seam
Gallon { $6\frac{5}{8} \times 7\frac{1}{2}$	$6\frac{3}{4} \times 7\frac{1}{2}$ $6\frac{5}{8} \times 7\frac{3}{4}$	$6\frac{3}{4} \times 7\frac{1}{4}$ $6\frac{1}{2} \times 7\frac{5}{8}$ $6\frac{5}{8} \times 7\frac{1}{2}$
$\frac{1}{2}$ Gal. { $5\frac{3}{8} \times 5\frac{7}{8}$	$5\frac{5}{16} \times 6$ $5\frac{1}{4} \times 6$	$5\frac{3}{8} \times 5\frac{3}{4}$ $5\frac{1}{8} \times 6\frac{1}{16}$
$\frac{1}{4}$ Gal. { $4\frac{1}{4} \times 4\frac{3}{4}$ $4\frac{3}{16} \times 4\frac{7}{8}$	$4\frac{1}{4} \times 4\frac{7}{8}$ $4\frac{3}{16} \times 5\frac{1}{8}$	$4\frac{3}{16} \times 4\frac{7}{8}$ $4\frac{3}{8} \times 4\frac{5}{8}$
$\frac{1}{8}$ Gal. { $3\frac{1}{2} \times 3\frac{5}{8}$ $3\frac{3}{8} \times 3\frac{3}{4}$	$3\frac{1}{2} \times 3\frac{3}{4}$ $3\frac{1}{2} \times 3\frac{7}{8}$	$3\frac{3}{8} \times 3\frac{3}{4}$
	Roll Seam	Palmer Star
Gallon { $6\frac{5}{8} \times 7\frac{1}{2}$ when open $6\frac{5}{8} \times 7\frac{5}{16}$ when closed		$6\frac{1}{2} \times 7\frac{3}{4}$
$\frac{1}{2}$ Gal. { $5\frac{3}{8} \times 5\frac{13}{16}$ when open $5\frac{3}{8} \times 5\frac{5}{8}$ when closed		$5\frac{1}{4} \times 6\frac{1}{8}$
$\frac{1}{4}$ Gal. { $4\frac{1}{4} \times 4\frac{3}{4}$ when open $4\frac{1}{4} \times 4\frac{9}{16}$ when closed		$4\frac{3}{8} \times 4\frac{7}{8}$ $4\frac{1}{4} \times 5$
$\frac{1}{8}$ Gal. { $3\frac{3}{8} \times 3\frac{7}{8}$ when open $3\frac{3}{8} \times 3\frac{11}{16}$ when closed		$3\frac{1}{2} \times 3\frac{3}{4}$ $3\frac{1}{2} \times 3\frac{7}{8}$

NOTE.—The gallon and half gallon cans hold full volume to within $\frac{1}{2}$ inch of top, and the quarter gallon and eighth gallon cans to within $\frac{3}{8}$ inch of top.

The Scientific Section herewith presents the White Pigment, Color and Vehicle Nomenclature Tables, which they have worked out and which will be of value to the manufacturers and their chemists in many ways. Until more definite knowledge is obtained regarding legislation that requires the honest labeling of paints, the Section intends to recommend the use of these tables to guide the manufacturer in properly labeling his products.

CHAPTER X.

TABLE OF VEHICLE CHARACTERISTICS.

	Qualities.	Defects.
Spirits of Turpentine or Turpentine	Distilled from pine sap. Should be a water white liquid of penetrating odor and characteristic pine aroma. Has excellent flattening qualities and increased spreading and working properties over other solvents in paints. Slow evaporative and solvent properties valuable. Aids drying of paint. Should show less than 2 per cent. residue on evaporation and should not stain paper. Refraction Index and Polymerization valuable aids to detect adulteration. 90 per cent. distills below 170 degrees C. Flashing point not below 105 degrees F. Boiling point 156 degrees C. Specific gravity .862 to .870 at 60 degrees F.	Long exposure causes loss of solvent and flattening properties, and it becomes viscid, due to absorption of oxygen. Irritant to system and kidneys.
Wood Turpentine	Obtained by destructive or steam distillation of pine knots, stumps, etc. Gravity sometimes ranges as high as .91. Can be made to correspond to every test for Pure Gum Spirits.	When not properly refined may contain tarry substances, pyroligneous acid creosote, etc. Does not flat or dry as well as gum spirits. Affects eyes and kidneys. Odor suggestive of aldehyde like substances. Differs from turpentine in having less pinene and more turpenes.
Linseed Oil or Flaxseed Oil	Up to the present time no material has been discovered that is its equal or superior as a general vehicle for paints. A drying oil obtained by crushing and pressing, or extraction by solvents from flaxseed, at certain temperatures. Should be golden yellow in color when raw, cold pressed oil being lighter than warm pressed. Should not contain over 5 per cent. (incidental) hemp or rape seed, or other vegetable oils. Should be free from mineral, rosin or fish oils. Adulteration may be detected by saponification values, iodine or bromine values, and specific gravity, which should range from .93 to .94 at 60	May absorb moisture during process of drying and hardening, tending to make the paint porous. The dried film may become hygroscopic.

TABLE OF VEHICLE CHARACTERISTICS—Continued.

	Qualities.	Defects.
	degrees F., saponification value 192 and iodine number 172, although samples of pure oil have ranged from 168 to 185. Ageing and settling are important features in its commercial value for manufacture of paint and varnishes. Viscosity, flash point, fire point, acid number, ash, drying test, all of value in testing an oil. Break test especially valuable when oil is to be used in varnishes.	
Boiled Linseed Oil	Made by heating raw oil with metallic oxides and salts for the proper length of time at a temperature of 212 degrees F. and upwards. Drying qualities are aided by the addition of lead, iron and manganese oxide or pure drier, during boiling at a temperature between 392 and 545. Iodine number may be quite low.	Excessive use in paint may cause chalking.
Bleached Linseed Oil	Bleached by the fire method, acid and steam method, oxidation and other methods. Should be neutral and free from water and salts.	
Blown Linseed Oil	Coming into use for special purposes. Heavy and viscous.	
China Wood Oil	Lighter, thicker and faster drier than linseed oil. Obtained from the nut and seeds of the Chinese Tung tree. Used to harden and dry, and in varnishes in place of wax.	A new and promising material now being investigated. Dries flat.
Benzol Solvent Naptha	By-product in the destructive distillation of coal. Volatile liquid of powerful solvent qualities. Agreeable odor. Used in varnish removers, asphalt and coal tar paint. Useful for priming purposes on interior work. Gives smooth spreading.	Should not be used in finishing coats, because of its effect upon other coats.
Benzine or Naptha	So called when below 95 degrees F., flash. The familiar volatile known as naptha or painters' spirits. On either paraffine or asphaltum	

TABLE OF VEHICLE CHARACTERISTICS—Continued.

	Qualities.	Defects.
(†) Paraffine Spirits	base. Boiling point 120-150 degrees F. So called when above 95 degrees F., flash, and on a paraffine base. Evaporation value about 25 minutes without leaving stain on paper. Penetrative value at least equal to turpentine. Boiling point 150-210 degrees F.	
(†) Asphaltum Spirits	So called when above 95 degrees F., flash, and on an asphaltum base. Fully adequate solvent properties for oil paints. Unlike benzine, these spirits possess fine flowing qualities and good flattening qualities. Better solvent for hard gums. Oxygen carrying qualities.	

*Both Paraffine and Asphaltum Spirits could be described as Petroleum Spirits if there be no desire or need to distinguish these two materials.

Water A reasonably small percentage of More than a slight
Practice (allowed by State authorities) water improves the non-settling percentage of water
is to disregard presence of water in paint up to 1.5% of the fluid portion, conditions and improves the brush- means an emulsified
this amount being recognized as accidental or incidental to the process of manufacture. All water beyond 1.5% in the fluid portion to be stated on label. ing qualities, also tends to satisfy paint, and when used
 the chemical activity of non-stable in such excess is a
 pigments, such as corroded lead, cheapener and adul-
 during process of manufacture, terant.
 this decreasing chemical activity
 of the applied paint, and promot-
 ing durability of the job.

LIQUID DRIERS.

Volatile products used in paint which by their action hasten natural oxidation and thus aid in converting the film of linseed oil partly to linoxyn, thus assisting nature. These artificial driers are made by boiling linseed oil with certain metallic oxides and salts, as of lead, iron and manganese, with subsequent thinning with solvents. Their action is catalytic, and when used to excess, they carry on oxidation to such an extent as to destroy the elasticity of the paint coating.

JAPANS.

Manufactured by dissolving metallic salts and oxides with varnish gums and linseed oil at a high temperature with subsequent reduction with benzine or turpentine, etc.

METHODS USED IN TESTING JAPANS AND DRIERS.

Physical tests of drying properties and nature of film valuable in determining quality. Acid value, nature of ash, percentage of volatile oils, are chemical tests applied.

COLOR NOMENCLATURE TABLE.

Technical Name.	Chemical or Optional Name.	Description.
Chrome Yellow	Lead Chromate	Formed by simultaneous precipitation of Lead Sulphate and Lead Chromate. Considered pure when containing Lead Sulphate up to 60%. The Lead Sulphate being necessary for the production of shade. If a mechanical mixture, it must be indicated.
Lemon Chrome Yellow	Pure Chrome Yellow	
	Lead Sulpho Chromate	
Medium Chrome Yellow	Neutral Lead Chromate	Should be 98% pure color. When made from Acetate of Lead, small percentage of Lead Sulphate allowable.
	Pure Medium Chrome Yellow	
Orange Yellow	Basic Lead Chromate	Composed of varying amounts of Basic and Neutral Lead Chromate. Should be 98% Lead Chromates.
	Pure Orange Chrome Yellow	
Orange Yellow D. D.	Basic Lead Chromate	Same as Orange Yellow and precipitated upon a Lead white compound. Should be 98% of Lead compounds.
	Pure Orange Chrome Yellow D. D.	
Naples Yellow	Lead Antimoniate	Calcined Product. Should be 98% pure.
Zinc Yellow	Zinc Chromate	Basic Chromate of Zinc. 98% pure color. Permanent. Good body. Resists sulphur gases.
American Vermilion	Basic Lead Chromate	Basic Lead Chromate containing small percentages of Lead Sulphate and traces of other Lead compounds. Should be 98% of Lead compounds.
	Persian Scarlet	
	Chinese Scarlet	
	Imperial Scarlet	

COLOR NOMENCLATURE TABLE—Continued.

Technical Name.	Chemical or Optional Name.	Description.
English Vermilion Trieste Vermilion Chinese Vermilion	Sulphide of Mercury	These are artificial products. Act like natural vermilion. Identical in composition with natural vermilion.
Red Lead Minium	Tetra-Oxide of Lead	Made by submitting Lead or Lead compounds to oxidation by air and heat. Vary in shade and body. Producing brilliant vermilion with aniline dyes superior to Cinabar.
Orange Mineral	Teroxide of Lead	Base for Eosine Vermilions. Bright reddish orange powder. Stable, except when in presence of sulphur. Excellent for priming coats for steel. Made by process similar to red lead.
Indian Red	Iron Oxide	Valuable pigment made from Copperas, also from ground red hematite. Exceedingly fine. Permanent. If a natural product, may contain Silica or Silicates. Contains from 90 to 98% Ferric Oxide.
Scarlet Oxide	Iron Oxide Ferric Oxide when pure	Made from Copperas.
Bright Red Oxide	Iron Oxide	Made from Copperas. Contains Sesqui-Oxide of Iron, Silica, Calcium Sulphate, and sometimes Calcium Carbonate, percentages of all of which must appear on the label.
Tuscan Red		Ferric Oxide with white base, stained with Aniline or Alizarine Dyes, prefer-

COLOR NOMENCLATURE TABLE—Continued.

Technical Name.	Chemical or Optional Name.	Description.
		ably the latter, percentages of all of which must appear in label. Quite permanent if prepared with Alizarine Dyes.
Venetian Red		Originally made by a precipitation together of Sulphate of Iron and Calcium Hydroxide, and calcining the product—usually produced by calcining an admixture of Copperas and Terra Alba. Also by grinding native Red Oxide with a suitable white base. In each case the percentage of components must be stated. Should contain at least 20% Sesqui-oxide of Iron.
Dutch Pink	Italian Yellow	Quercitron Lake, on a base of Aluminum Hydrate, Calcium Carbonate and Gypsum. Normal analysis should be given.
Dutch Pink	(Imitation)	Yellow Aniline Dye-stuff precipitated on Barium Sulphate base. Analysis must be stated.
Alizarine Lake		Made from Alizarine precipitated on Alumina Hydrate, Phosphate and traces of Lime. If of normal composition, analysis need probably not be given.
Paranitranaline Permanent Red Para Red		Paranitranaline and Beta Naphthol precipitated on Orange Mineral, Red Lead, or a white base.

COLOR NOMENCLATURE TABLE—Continued.

Technical Name.	Chemical or Optional Name.	Description.
Cinnabar (Natural Vermilion)	Sulphide of Mercury	<p>Most permanent of vermilions. Percentage of white base and coloring matter should be stated.</p> <p>Darkens in light and turns brown. Should be 98% pure.</p> <p>Important and permanent color found in nature, already reinforced. Hydrated and rehydrated Ferric Oxide permeating a clay base and containing considerable Man- ganic Oxide. Deeper in color than Ochre, and less opaque.</p> <p>Raw Siennas are rich tones and tints of yellow. Burnt Siennas, produced by calcination, are rich tones and tints of red brown.</p>
Siennas (*)		
Ochres (*)		<p>Important, perma- nent natural yellow color found rein- forced with Silica, Gypsum, Alumina, etc. Consists of hydrated Ferric Sili- cate of Aluminum, permeating a clay base, and when burnt its shade may be varied.</p>
Umbers (*)		<p>Valuable brown earth pigments. Similar in composi- tion to Siennas and Ochres, and found in same way. Varies</p>

COLOR NOMENCLATURE TABLE—Continued.

Technical Name.	Chemical or Optional Name.	Description.
		in shade according to the proportions of Ferric and Manganic Oxides present. Calcination produces a "warmer" color, and this product is called Burnt Umber.
<p>(*) [†]The manufacturer of paints should specify under the Analysis of Colors on his label the amount of ferric oxide present, in this line, when ground in oil and sold as oil color.</p>		
Vandyke Brown (Natural)	Cologne Earth or Cassel Brown	Found in nature and produced by the decomposition of organic vegetable matter, such as Peat. Its composition is variable, in accordance to the amount of earthy material present, which, with the carbon and hydrocarbons, give it the color. Analysis may perhaps be required.
Vandyke Brown (Artificial)		Composed of Oxide of Iron, Drop Black and Chrome Yellow or Ochre. Composition must be stated.
Mineral Brown	When of the particular grade may have bracket so designating, for example: (Princess Metallic) or (Princess Mineral)	Calcined Natural Earth with about 45% of Ferric Oxide. Sometimes enriched with Calcined Pyrites. Normal analysis must appear on label.
Chrome Green (*)	Pure Chrome Green (Yellow Tone)	Made by simultaneous precipitation of Chinese Blue and Lead Chromate. Mixing Yellow and Blue will not give the same bright shade, (affected by alkalis,) but chem.
	* So-called "Commercial Pure, etc."	
	(*) So-called "Commercial Pure Chrome Green" (paint) contains 75 to 80% of reinforcing pigments used to diffuse and brighten the dense color. Analysis must be given in analysis of color.	

COLOR NOMENCLATURE TABLE—Continued.

Technical Name.	Chemical or Optional Name.	Description.
		ical analysis cannot detect the inferior mechanical mixture. Should be 98% pure color.
Chrome Green	Pure Chrome Green (Blue Tone)	Same as above, but requiring about 30% Lead Sulphate, which must show in label formula.
Bottle Green		A mixture of Bone Black, Chinese Blue, Chrome Yellow and a little Zinc or Lead White compounds, percentages of all of which must show in label formula.
Bronze Green		True Bronze Green is a mixture of Bone Black and Chrome Yellow, and proportions must show in label formula.
Paris Green	Aceto-Arsenite of Copper	Poisonous nature prohibits extensive use in painting.
Verdigris	Basic Acetate of Copper	Mixture of Di- and Tri-Basic Acetates of Copper. Very little used.
Ultramarine Blue	Soda Blue Pure Ultra Blue	An artificial lapis-lazuli produced by fusing together Silica, Soda, Alumina, and Sulphur. Should not be used to excess with Basic Carbonate-White Lead, because of its sulphur content. Analysis of ingredients need not be stated.
Prussian Blue	Ferric Ferrocyanide of Iron Paris Blue Chinese Blue Berlin Blue	Made by precipitation of Ferrocyanides with soluble

COLOR NOMENCLATURE TABLE—Continued.

Technical Name.	Chemical or Optional Name.	Description.
	Antwerp Blue Milori Blue Steel Blue	Iron Salts with subsequent oxidation. Contains small percentages of Potash or Soda, and sometimes of Alum and Chrome. Alkaline pigments destroy color. Analysis need not be given if of normal composition. Not considered safe to use with Basic Carbonate White Lead.
Bone Black Drop Black		Made from Animal Bone. Should be 12-15% carbon. Slow drier. Normal analysis must be given. Different tone and much less tinting strength than Lamp Black. More body. Contains Calcium Phosphate.
Ivory Black		Gives an intense black. Formerly made from Ivory Chips, now usually from carefully selected Animal Knuckles. Should be 15-20% Carbon. Presence of oily matter detrimental because of non-drying nature. Normal analysis must be given. Contains Calcium Phosphate.
Carbon Black	Gas Black	From incomplete combustion of gas. Is intensely black in color. Non-crystalline. Good tinting power. No analysis required if of nor-

COLOR NOMENCLATURE TABLE—Continued.

Technical Name.	Chemical or Optional Name.	Description.
		mal composition. Should be 98% carbon.
Mineral Black		This is an inert black, usually composed of Carbons, Slag and Slate. Deficient in coloring value. Composition required on label.
Lamp Black		From combustion of oils. Very uniform and averages 98% pure Carbon. Very fine. Permanent. Not as black as Carbon Black, but yields very clear tints. No analysis required if of normal composition. Great tinting strength.
Graphite (Natural)		Allotropic form of Carbon with Silica and Alumina found in nature. In two forms, amorphous and flaky. Brownish black mineral, greasy to the touch and permanent to all reagents. Excellent as a lubricant. Possesses great spreading capacity. Contains Silica or Clay, sometimes both. Analysis required.
Graphite (Artificial)		Same as above. Uniform amorphous and very fine. In paint requires admixture with Silica or other pigments to give tooth. Analysis required. Best contains 90% Carbon. Contains Silica or Clay, sometimes both.

COLOR NOMENCLATURE TABLE—Continued.

Technical Name.	Chemical or Optional Name.	Description.
Vine Black		Dense black, formed by charring grapevine or lees. Sometimes alkaline. Composition required on label.
Charcoal		Sometimes used in black paint for iron work. From charring of wood. Liable to saponify oils because of alkalinity. Can be stated on label as vegetable charcoal.

CHAPTER XI.

White Pigment Nomenclature.

<i>Pigment</i>	<i>Optional Bracket When of the Particular Grade</i>
Zinc Oxide	(Horsehead) (Western) (Mineral Point) Etc., Etc.
White Lead	
*Basic Carbonate-White Lead (Corroded White Lead)	
Carbonate White Lead or Precipitated Carbonate-White Lead	(Precipitated)
Sublimed White Lead	
*Basic Sulphate-White Lead	(Sublimed)
*Basic Sulphate-Sublimed Lead	
Zinc Lead White	
Lithopone	(Green Seal Beckton) (Gold Seal Beckton) Etc., Etc.
*Government Agricultural officials prefer to have the hyphen left out.	

<i>Pigment</i>	<i>Optional Bracket</i>
Barium Sulphate or Barytes	
Precipitated Barium Sulphate or Barium Sulphate	(Blanc Fixe)
Aluminum Silicate	(China Clay)

*Magnesium Silicate (Asbestine)	(Asbestine)
*Magnesium Silicate (Talcose)	(Talcose)
Calcium Carbonate	(Whiting) (Paris White) (White Mineral Primer) (White Mineral Primer Crystalline)
Hydrated Calcium Sulphate or Calcium Sulphate	(Terra Alba) (Gypsum)
Partially Dehydrated Calcium Sulphate or Plaster Paris or Dental Plaster	(Calcined Gypsum)
Dehydrated Calcium Sulphate or Dead Burnt Calcium Sulphate	
Silica or Silix	(Quartz Silica) (Infusorial Earth) (Decomposed Silica)

*The Asbestine or Talcose varieties easily distinguished under the magnifying glass.

Report of R. S. Perry
to the
Bureau of Promotion and Development.
October 21, 1907.

October 21, 1907.

Mr. Gregg, Chairman,
Bureau of Promotion & Development,
Paint Manufacturers' Association,
New York City.

Dear Sir:—

In accordance with your request I give you herewith a report of the scientific work of the Bureau during the past year leading up to the organization of the Scientific Section and an outline of the scope of the work for this section for the future. Originally no scientific work was contemplated in connection with the Bureau or deemed necessary in connection therewith. During this past year of 1907 the necessity for scientific aid to the Bureau became apparent and the necessity for this work more and more pressing. The legislative crises brought to the Bureau the *emergency* and the *necessity* of protecting the interests of each member of the Association regarding the materials used in paint manufacture.

The use of what are known as re-enforcing pigments is necessary and customary with every paint manufacturer in preparation of certain colors and tints. Many manufacturers of high grade paints use these same re-enforcing pigments in justifiable quantities and percentages throughout their line of products. The legislative crises brought to the Bureau the necessity of justifying the proper use of these re-enforcing pigments and the Bureau needed technical and scientific data to bring the public mind to reasonable and proper acceptance and knowledge of these materials and of their proper use.

It is proper at this point to state the gratitude of the Bureau to a number of manufacturers who aided the Bureau with the use of their laboratories and the help of their chemists in preparing data and formulating technical literature for the use of the Bureau. The paint catechism prepared by our secretary, Mr. Heckel, was part of the work of the Bureau in meeting this legislative crisis.

During this year of 1907 the further emphasis upon the necessity for a scientific section came in the shape of work for the architects to whom it was necessary to justify ready-mixed paints from an engineering standpoint and deal with our product upon the basis of its physical and chemical contents.

The work with the master painter undertaken by the Bureau in preparing a new product for them again called for use of laboratories and technical men.

In all of these matters the Bureau found itself dependent upon the use of chemists and laboratories of its members and other friendly paint manufacturers and came to realize that from these laboratories and chemists already working under full pressure of routine work the best results could not be obtained for the benefit of the Association.

The problem of labeling which is being forced more and more upon the members of the Association is developing upon the Bureau, both for its own work and in aid of the legislative committee, the necessity of further scientific work.

In all this work of the past year it has become more and more apparent to the Bureau that great improvement could be brought about for the benefit of each member of the Association in centralizing and distributing much necessary data now scattered through the laboratories of various paint factories, data which could and which should, without injury to any one member of the Association, properly become the common property of the Association. The paint chemists pursue different methods, often unnecessarily complicated, and while necessary in obtaining absolute theoretical results, these methods can, with benefit, be substituted by methods

giving commercial accuracy and methods both simple and time-saving. The Bureau has had no laboratory or chemists of its own, and the particular problems undertaken show both the necessity for this aid to the Bureau's work and also the possibilities of helping each member of the Association through such work.

The scientific work of the Bureau during the year 1907 has therefore consisted in guiding technical and scientific statements in the literature of the Bureau, particularly in the catechism, also preparation of the work presented to the architects at their meeting in Detroit and the arranging for the compiling and unifying of the proper methods of analyses. In addition to this work, an address in the interests of the Association at large was made at the annual meeting of the International Association of Master House Painters and Decorators at Boston, on the manufacture of the dry colors used by the paint manufacturers, and the dry colors were actually manufactured on a small scale before the convention, arousing their great interest.

In September, one month ago, the Bureau finding that it has before it much greater possibilities along these same lines than the work of 1907, as above described, and realizing the great benefit possible from this work that would accrue directly to each individual member of the Association, created the scientific section of the Bureau appointing the writer as Chemical Director and associating with him in the section Mr. Elliott and our secretary, Mr. Heckel.

In order to place this work upon a very high plane of scientific and technical integrity and to give weight to the results and findings of this section, the Bureau authorized the organization of a consulting board of five members to consist of prominent chemists and physicists of national standing connected with public investigation and work along chemical and architectural lines and also connected with pure food and paint investigations.

The names have already been laid before the Board and have been approved and the gentlemen are now being asked to accept these positions.

Dr. Dudley, well known to every paint manufacturer, has agreed to come to this Board. He is well-known as Chief Chemist of the Pennsylvania Railroad Company and of the Bureau of Explosives and Inflammables. He is the president of the American Society for Testing Materials and holds responsible positions of a similar nature.

Mr. S. S. Voorhees is the second to accept a position upon this Board. He is connected with the United States Government Architectural Office and Laboratory and is an authority upon investigating the results of paint exposures.

Members of this Association know of his important work and his report as chairman of the Committee of the American Society for Testing Materials in charge of the paint testing upon the Susquehanna Bridge for the Pennsylvania Railroad.

The members of your Bureau have thus far prepared the technical data themselves or guided its work in their own laboratories, and have found the amount of work which is needed to protect your interests and which the Bureau has undertaken for you, *too great* in its importance to permit of its being done by them in view of their many other duties.

This section will, therefore, have employed under guidance of its chemical director an investigating chemist trained and competent to handle particular questions involved and an assistant analytical chemist. The work immediately ahead of the Scientific Section would warrant the employment of a larger force, but it is deemed wise to feel our way cautiously and get results with the force thus far agreed upon before considering many matters of vital importance to paint manufacturers which would require larger expenditures.

The investigation into thinners and turpentine substitutes is a problem of vital importance to each member of the Association, and these investigations should be conducted as energetically as possible and with the greatest care for the benefit of the Association at large by the Scientific Section, but the work already on hand for 1908 will probably absorb all the time and efforts of the two chemists now authorized

by the Bureau for this section. The approaching exhaustion of the turpentine supply would warrant the exclusive efforts of a couple of chemists on this one problem, of *possible* and *proper* substitutes, for several years.

The Scientific Section will continue to carry on the same class of work for the year 1908 that has been reported upon above as accomplished during the past year, and will thus co-operate with the Commercial Section and be at the disposal of the Legislative Committee for such facts and technical knowledge as they may need.

Many members of the Association are now confronted with the intricate problem of preparing formula labels for their products and the technical side of the Bureau during the past year has had to cope with many of these problems under the guidance of the Legislative Committee and with reference to the technical and scientific requirements of stating in a correct and practical manner the contents of the package.

This section cannot make analyses for the benefit of any member of the Association and its analytical work will be only such as is necessary for the common interest of all and to aid the other sections of the Bureau and the Legislative Committee.

But the Scientific Section is at the disposal of any member of the Association for correspondence looking towards technical advice and information connected with problems of formula labels, and in supplying correct technical expressions, in proper grouping of the contents of packages on the formula labels, this under supervision of the Legislature Committee.

The earnest co-operation of the various companies and their laboratories is earnestly desired and the work of the Scientific Section can be immediately benefited by such co-operation. It is especially requested that the chief chemists of these various corporation laboratories be authorized to correspond freely with the Scientific Section with a view to comparing analytical methods and technical control (both chemical and physical) of the raw materials of the paint products.

For the year 1908 the Scientific Section has been given exclusive use of a special research and very perfectly equipped laboratory belonging to a paint factory.

A dangerous problem and a new difficulty confronts the paint manufacturer of to-day. The Pennsylvania Railroad has decided to formulate and enforce very broad and comprehensive regulations regarding the transportation of explosives and inflammables, paints and varnishes of all descriptions included. It is needless to say that this railroad is the leader in new regulations of this kind and is followed by all the other Trunk Lines in the country. The regulation has proposed to cover paints of all descriptions, and it has been planned to require that any package containing paint for shipment must have placed upon it a prominent label, marked inflammable, and with caution against placing near radiators or other sources of heat, and against exposure to direct sunlight.

Every paint manufacturer at once recognizes that a regulation of this kind will fill every dealer's store with cases of paint proclaiming the contents to be dangerous, calling for insurance complications for the dealer and warning the house owner against ready-mixed paint as a dangerous article, should he desire to keep it upon his premises. Two members of your Bureau, Mr. Elliott and the writer, caused urgent representation to be made before the Pennsylvania Railroad, and everything possible was done to persuade this road to substitute for the proposed warning label, one which would not bring this injury upon our business.

Some success was apparently made along the lines desired, but the Scientific Section having later on addressed itself to this matter finds our suggestions and arguments after all failed and that the details of the regulations along the original lines are now under consideration in the Bureau of Explosives and Inflammables and have been referred to Mr. Dudley, of that Bureau.

The Scientific Section has taken the matter up urgently with Dr. Dudley, urging upon the Bureau of Explosives that it is only fair to ready mixed paints to determine a danger

limit in the percentage of volatiles, say, for example, 12 per cent., with the idea that only goods above the danger limit should receive the caution label, while those below the danger limit should be free from regulations providing the package has upon it the label showing the name of the manufacturer and that no goods in the package exceed the danger limit.

House paints constitute the great volume and the still greater revenue in Interstate Commerce of all our paints and investigation will probably show this to be well over 80 per cent. of the total transportation of paints.

With certain exceptions, these house paints contain a very moderate percentage of inflammable materials or thinners, and because of this low percentage such house paints should not come under the regulations for explosives and inflammables requiring caution label.

The work planned by this Section should give to each manufacturer in the course of the next two years an amount of practical, useful and really necessary data, which could hardly be obtained from the laboratory of anyone manufacturer, however large, because in the individual laboratories there is steady pressure of routine work and each manufacturer will assuredly find that he is receiving information and guidance on the technical side of his business which will more than repay him for his entire contribution to the Bureau, and which he could not obtain from his own laboratory, however large, for many times the sum of his contribution.

Under the most careful conditions, the work of this section will involve a considerable outlay of money and, therefore, the Scientific Section urges that the Bureau impress upon the members of the Association the necessity of large subscriptions to the Bureau for the year 1908.

Your very respectfully,
R. S. Perry.

FIRST REPORT ON THE TEST FENCES ERECTED BY THE SCIENTIFIC SECTION.

There is a desire among certain manufacturers to raise the standard of excellence in the paint trade and give their best efforts to wipe out misunderstandings and prejudices, upon the part of the public, regarding the usefulness of many important new materials used in the manufacture of paints.

This brings us face to face with the fact that it is necessary that practical tests should be made—made not only by practical men, but made along scientific lines in order to arrive at definite conclusions.

Object of
Tests

The advisability of such tests is apparent at the outstart, and many who are interested in the honest paint legislation, which is at present occupying the attention of the whole industry, express regret that these tests had not been made ten years ago, so that definite and indisputable evidence might be at hand to demonstrate to misinformed lawmakers the unfairness of restricting manufacturers of paints to a certain few so-called statutory pigments which have been instilled into the minds of these legislators, as the only proper ones that should be used. If these pigments in different combinations prove their value over all other combinations, well and good; but if we find that other pigments may be incorporated up to a certain extent, and find out the approximate limit of the use of these reinforcing pigments in improving the paint, then we will have gone a step higher in the production of a superior product. Authorities on paint differ as to the value of some pigments and their proper percentage in the composition of paints, but all agree that the BEST PAINT is yet to be produced. It would be idle for anyone to claim that a certain combination of pigments produces the best and only honest paint, and then lay back satisfied that no further progress can be made and endeavor to smother the ambition of the

Statutory
Pigments

benefit a paint, if they do benefit, and just how they serve their intended purpose is a question which we hope these tests will show. Certain of the many paints placed upon these fences contain these inert pigments in varying percentages, so that conclusions may be drawn showing the investigator who is trying to advance the industry with his scientific or practical researches and studies.

Scientific investigation has shown that reinforcing materials lend certain qualities to paint, but these materials should be used with scientific precision, understanding and in moderation. The public is becoming more and more discriminating and the progressive and the reputable manufacturer does not indulge in addition of reinforcing pigments to his paint before he has found out the proportions in which such pigments become beneficial.

Use of
Reinforcing
Pigments

The percentages of the so-called reinforcing pigments, such as silica, blanc fixe, aluminum silicate, magnesium silicate, calcium carbonate, calcium sulphate, etc., which safe limit of these various pigments, beyond which the manufacturer must not go in the compounding of paints. To show the proper value, not only of these reinforcing pigments, but of the various white base pigments, such as zinc oxide, basic carbonate white lead, basic sulphate white lead, zinc lead white, lithopone, etc., will guide the manufacturer in producing, and the public in choosing, paints, having that trinity of requirements, namely, hiding power, covering and spreading power, and the maximum durability—those qualities which the master painter looks upon as essential. When these different formulæ have been tried out and the work has demonstrated the value of the different pigments, then the manufacturer believes he will have certain data which will justify the honest products of the day and will condemn the dope. The master painter will have these tests to aid his judgment in choosing between the various formulæ, and the architect will have at hand for his inspection results of which he may take advantage in gaining knowledge upon which to base his future specifications.

Value and
Qualities of
Pigments

Result
of Tests

Vehicle
Characteristics

The question of vehicle is as important as that of pigment, and demands honest products and proper treatment. The painter wishes to secure a paint which, when dry, will be improved by the composite characteristics of the contained pigments, and which will be strengthened by these different pigments to a high point of elasticity and strength, or of such an elasticity that there is no undue strain on the surface upon which it is used and which will, at the same time, have excellent sealing properties, excluding gases and vapors of the air which would tend in some cases to alter the pigments. He requires a paint that will brush and spread properly, and one which he can reduce in accordance with the nature of the wood to which he is applying the paint in order to satisfy the absorbing properties of the wood and properly bind the pigments to the surface.

Colors

The paints used in the test have been applied in white, yellow and gray, the latter two colors having the same percentage composition as the white, with the exception of the small per cent. of tinting base used.

Permanency
of Colors

The various colors, such as reds, blues and greens, have been tried out as special tests upon panels primed with different white base pigments in order to determine what base to use for certain of these colors which in the past have given the painter much difficulty after they have been applied, some fading, some darkening, and others showing very peculiar and troublesome results.

Climatic
Conditions

The climatic conditions, peculiar to the places where these fences have been erected; Atlantic City, where the salt air has an accelerated destructive effect upon paint, and Pittsburg, where the coal and sulphur gases act with remarkable force; will serve to give in a short period,

some idea of the wearing quality of the different combinations.

Owing to the lateness of the season and inclemency of the weather when this work was started, it was deemed inadvisable to place the panels upon the fences and do the painting outside. This would have caused difficulty in drying and the painting of the different panels would have been subject to unequal conditions of application. Furthermore, the property of paint, when very cold, is to thicken and gelatinize or, expressing this in the vernacular of the painter, "to liver," and in order that we might be assured that the paints were being applied under fair and average conditions, it was deemed advisable that the painting should be done indoors under conditions of temperature and conditions of the atmosphere that would make our tests normal and valuable. A further advantage lies in the fact that the early part of the year is a season comparatively free from dust, and consequently when our panels were screwed on the fence there was absence of this unfavorable feature. For this reason a building was rented within close proximity to the Atlantic City fence and previous to the painting, was used for the storage of the panels and the paints. In this building were placed proper scales and measures necessary for the tests. All the paint was carefully looked after, and no one allowed in the building without proper authority.

Object
of Inside
Application

The painting of the panels was done in this building by a painter selected by the Master Painters' Association of Pennsylvania, in the presence of the inspector of the fence. When the panels were finished they were removed and placed in their proper position on the fence.

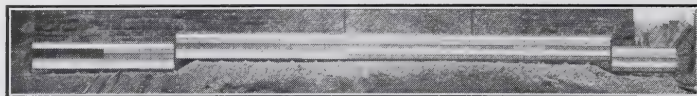
Committee E, of the American Society for Testing Materials, had supervision over these tests, and the chairman of the committee, Mr. Job, had his inspector on the ground throughout the work.

Committee "E"

The Philadelphia Branch of the Master Painters' Association appointed Mr. Butler official painter of the fence, and Mr. Butler's painter and inspector were present with Mr. Campbell, the inspector from the Paint Manufacturers'

Association throughout the work.

At Pittsburg, where the fence was under the supervision of the Carnegie Technical Schools, Prof. James, chairman of the Fence Committee, was represented by a man in similar capacity of weigher and inspector. At



Pittsburg Test Fence

Pittsburg the local branch of the Master Painters' Association also appointed an official painter, Mr. A. C. Rapp, whose inspector was present throughout the work. This work was also done under the supervision of Mr. J. B. Campbell, inspector for the Scientific Section of the Paint Manufacturers' Association.

Mr. Henry A. Gardner, chemist to the Scientific Section and supervisor of the test fences, herewith presents his report on the construction and arrangement of the tests. Supplementary reports of the inspectors follow.

R. S. PERRY, *Director.*

Scientific Section, Paint Manufacturers' Association, Phila., Pa.

Mr. R. S. Perry, Director,
Scientific Section,

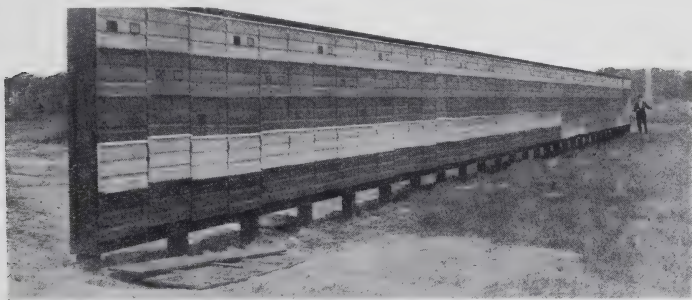
Paint Manufacturers' Association of the U. S.

DEAR SIR:—The following is a report on the construction and arrangement of the Atlantic City and Pittsburg Test fences:

LOCATION OF FENCES.

At Ventnor, three miles below Atlantic City, on the Atlantic Coast, a site was selected for the erection of the first fence. The site is 200 feet long and 10 feet wide, running North and South within the following boundaries: Between Mobile, Arctic, Atlantic and Savannah avenues, and within 100 yards of the salt water. This fence runs North and South, giving Eastern and Western exposure.

Site
Atlantic City



Another View of Atlantic City Test Fence

The site for the Pittsburg fence is at Carnegie Institute. The fence is located upon a high bluff overlooking the ravine, opposite the Women's Building, and this fence runs East and West, giving a Southern and Northern exposure, the Northern exposure being subjected to smoke and fumes wafted up from various smelting works. Because of the high ground upon which this fence is placed, this exposure test will be most excellent.

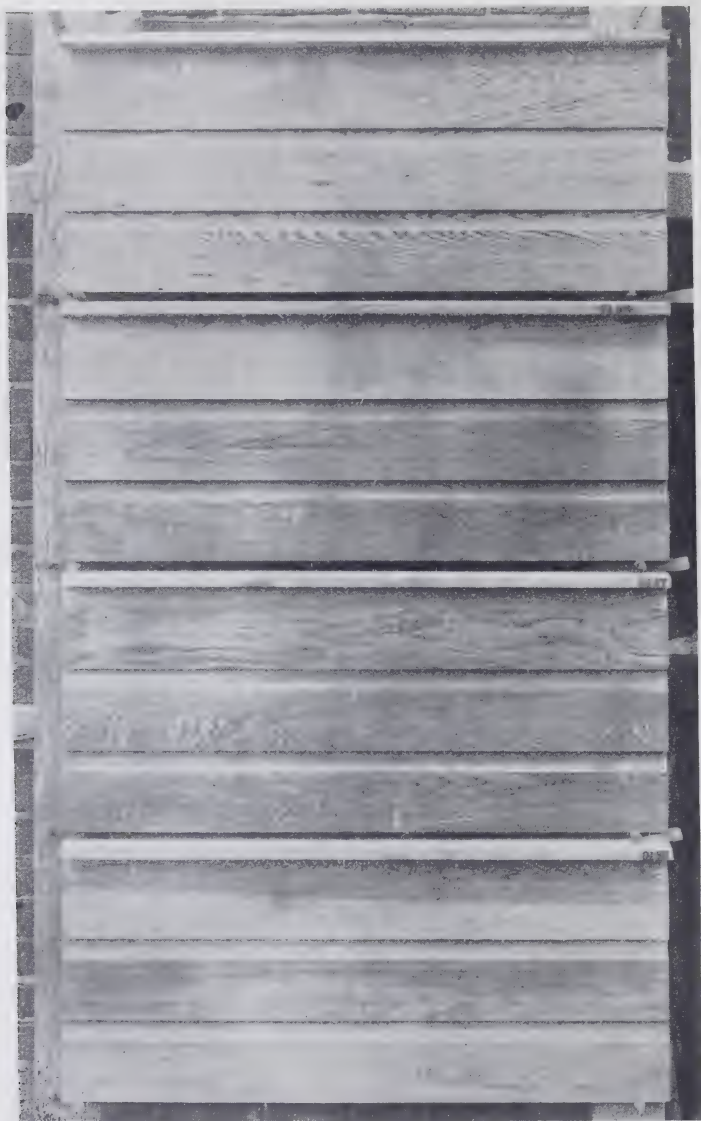
Pittsburg

CLASSIFICATION OF LUMBER.

The lumber used in the construction of the panels for these fences was selected with exceptional care. First,

Inspection

a large amount of this lumber was secured after it had been kiln dried for ninety days at an even temperature,



Cypress Panels

and subsequently weathered for ninety days in the lumber yard. A large amount of this lumber was then selected by an expert lumber classer and sent to the carpenter with specifications for the panels. After the carpenter had finished 1,600 of these panels in the various woods used, namely, white pine, yellow pine and cypress, the expert lumber classer was again engaged to look these panels over thoroughly and to reject any panels which he thought it would be unfair to use for a test of this nature, so that in the application of any formula to the panel it could not be claimed that the formula was injured by the condition of the wood of the panel selected. Out of the 1,600 panels, 1,200 panels were selected for the two fences.

Moisture exists in wood in two conditions: within the substance of the cell walls and in the pores, or lumina, of the cells. The strength of lumber is indirectly proportional to the amount of moisture in the cell walls, and after these walls have been satisfied and have reached the fibre saturation point, addition of free water to the pores of the wood has no weakening influence.

The lumber selected for the panels having been brought back to the weathered condition after the kiln drying, naturally had opportunity to assume its fibre saturation point to the degree that weathering would promote this point, and being made into panels at this period, added moisture or moisture encountered under exposure after painting would not tend to cause swelling, warping or lessening of the strength of these panels.

Strength
of Panels

BRANDING.

The panels were all branded with a hot iron, consecutively from No. 1 up, and the different kinds of wood were noted by an abbreviated brand mark, W standing for white pine, Y for yellow pine, and C for cypress.



White Pine Panels

PHOTOGRAPHING OF PANELS.

These panels were placed in frames after they had been built and passed by the lumber expert. The camera was set upon a platform at a certain distance from the panels. The camera being then set up and accurately focused, the time and light conditions were noted, and from experiments it was found that an exposure of one second with a clear bright sky gave good results, the negatives showing wonderful detail. Every panel was photographed, and after making a print of the negative, these prints were placed in an album so that at any time the condition of any panel upon either fence may be noted by referring to the number of the panel and looking it up in the album, which will give a detailed photograph of the panel in question.

CONSTRUCTION OF FENCES.

Twenty-nine heavy yellow posts squared to 6 in. were set in the ground, 6 ft. 4 in. apart, to the depth of 4 ft., upon a concrete base. The dirt was solidly tamped around the posts and cement was used within six or eight inches of the top of the ground and supplementary braces of 2 x 4 studding were used.

Studding of 6 in. x 2 in. was used, running from one post to another, both at the top and bottom of the fence, thus forming a solid frame work, the bottom of which is over 12 in. from the ground. The bottom, as well as the top of each fence, is protected by heavy timbers so as to keep the moisture from the ground penetrating the lumber.

Twelve-inch plain white pine sheathing was placed on both sides of the frame work, forming a solid background which was painted with Prince's Metallic Brown. Upon this background on both sides were placed the panels, firmly set in place with round-headed screws which may easily be removed and the panel transferred to the laboratory for microscopical or other tests at any time desired. The

panels are three feet long, $15\frac{1}{2}$ in. high, made of German weather-boarding, three strips to a panel, firmly backed with braces, and nailed together in such a manner that no portion of the nails appear on the surface of same, thus preventing any staining of the wood from rust. Each panel is capped with a weather table running the full length of the panel and projecting 1 in. over. Each section of the fence accommodates ten panels on either side, making a total of 560 panels, on each fence.



Yellow Pine Panels

As nearly all the houses in this country are built of weather-boarding, we have selected this as being the most practical for the test. Ordinary weather-boarding is split diagonally from $\frac{3}{4}$ -inch lumber, and when placed together forms a very fragile panel. For this reason German weather-boarding was selected, as it fits closely together and forms a stout panel, thus preventing any spaces for the admission of moisture.

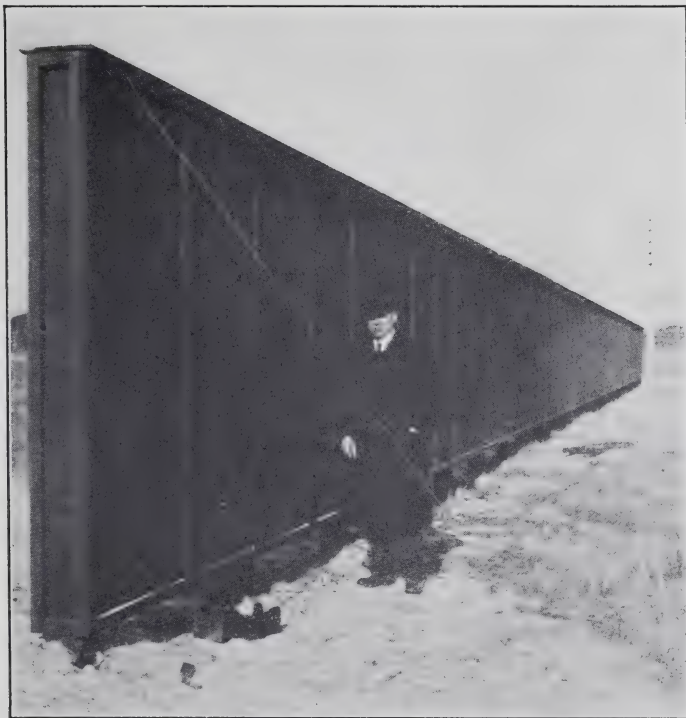
Because of the exposure of the Atlantic City fence to the sweep of strong sea winds, it was decided to brace each post with an 18-inch length of 2 in. x 6 in. studding, nailed crosswise about 6 in. below the surface of the ground.

Also to run guy wires from every second post alternately on both sides of the fence to stakes in the ground about five feet from the fence.

ACTINIC LIGHT TESTS.

Recent investigations into the nature of light have proven that it is the ultra violet invisible rays that are most energetic in setting up chemical action. These rays are also called actinic rays. It is the actinic rays which affect the photographic plate and give rise to many chemical reactions—consequently it is very important to know the relation of actinic light to the breaking down of paint.

Small plates of clear window glass and small plates of orange colored glass, size 5 x 2¼ inches, were placed



Atlantic City Fence Before Placing Panels

upon the middle weather-board of certain panels and held in place with tinters' tacks, and then a small amount of putty was placed around the edges to make the frames water-proof and so prevent the painted surface of the panel from being acted upon by the atmospheric changes.

At certain periods of time the glass slides will be removed from certain panels and observations made to determine whether the painted surface, protected from the actinic light rays by the orange colored glass, has suffered less than the painted surface not protected from actinic light rays by the ordinary white clear glass.

OPACITY.

In order that a test of the opacity of different paints to be applied to the fences may be made, a Maltese cross about four inches in height was stencilled upon each panel with lampblack and japan. As it would not have been fair to place the cross upon the wood before the first coat was applied, because of the difference in penetration of the vehicles and pigments used in the different kinds of paint, the cross on each panel was placed over the first coat.

The hiding power or opacity of the second and third coats of paint were observed after they had become dry.

Pigments in oil differ in their opacity in direct proportion to the difference between the refractive indices of the pigment and the refractive indices of the oil. However, it is necessary that a paint should protect the underlying surface from the destructive action of the actinic rays of light, and with this idea in view the investigation of the different combinations and the effect of the actinic rays upon them, also the effect of the visual rays of light, are results which we hope to obtain with these tests.

H. A. GARDNER,
Engineering Chemist.

To Mr. R. S. Perry, Director,
Scientific Section,
Paint Manufacturers' Association of the U. S.

GENERAL REPORT OF PAINT TESTS MADE IN ATLANTIC CITY.

On January 16th, the work on the Atlantic City test fence was started. The weather was fairly clear and dry for that season of the year, and the temperature was 50° F. inside the house where the paint was applied. The work was all done in the presence of the official inspector and weigher, Mr. Parthree for Committee E, of the American Society for Testing Materials; Mr. Pablo, painter for Geo. Butler, who was appointed official painter of the fence by the Master Painters' Association of Philadelphia, and myself, and was under the direction of Mr. H. A. Gardner, of the Scientific Section.

The panels were arranged in sections of six—first, two white pine; second, two yellow pine; and third, two cypress—by Mr. Parthree, and in their proper sequence with regard to the consecutive numbers branded on these panels.

PAINTS. The various paints were received in quart cans labeled "Paint Manufacturers' Association," and the number of the paint contained therein, but with no information regarding the name of the manufacturer who prepared the paint or other directions or information regarding reduction, etc. The various white leads used were received in kegs of 12½ lbs. each.

BRUSHES. A heavy 7-0 round bristle brush was used for the priming coat, so that the paint could be thoroughly worked into the wood. On the second and third coats a three-inch flat chisel brush was used. These were washed

and cleaned thoroughly in two washes of turpentine after applying one number of paint on all six panels in one color. The painter then worked out all the paint from the brush and set the brush in pot No. 1, turpentine. The inspector then washed them thoroughly in pots Nos. 1 and 2, of turpentine, then dried them and handed them to me, and, after carefully noting that no pigment was left in the brushes, they were thoroughly worked into the next number of paint to be used. In this way no pigment was carried over from one paint to another.

SHELLACKING. Orange shellac was applied to knots on the bare wood of those panels used for paints Nos. 8 to 27, and over the priming coat on those panels used for paints Nos. 1 to 8. The shellac was applied by the inspector, Mr. Parthree. By this method we have two conditions of shellacking, from which we hope to draw inferences later on as to the best method of application.

PRIMING COAT.

A full quart can of paint as received was placed upon a correct set of balances and the gross weight was taken in grams and the weight of the paint as received was marked on the weighing sheets.

The can was then opened and the contents was poured into a half-gallon enamel pot and thoroughly broken up and stirred well to bring the mixture to thorough incorporation. The consistency was then noted and one-half of this paint was transferred to two half-pint friction top cans, which were sealed and marked with the number of the paint and name of the fence, and later on one set of these cans was sent to the Scientific Section, and the other sent to Committee E, of the American Society for Testing Materials, for future reference and analysis.

Proper reduction was made for the priming coat of the balance of the paint in the enamel pot, and it was then ready

for application. The brush used for the priming coat was thoroughly worked into the paint and then the pot, paint and brush were placed upon the balance and the weight taken by the official weigher in grams, using the metric system throughout in this test. The pot was then handed to the painter who applied the paint to one panel. After proper application, the brush, pot and paint were then handed back to the weigher and reweighed, the difference in weight being the weight of the paint in grams used on the panel, recording same on the weighing sheet, also the number of the panel upon which the paint was applied and the kind of lumber. This method of procedure was followed throughout the tests on every formula and on every panel.

The drying of the priming coat was noted every twenty-four hours on the different woods and the penetration was observed at the same time. The priming coat was allowed eight days to dry, and during this period inspection was made as to the drying.

At this period a black cross was stencilled upon the end of the middle board of each panel with lampblack. This was placed there in order that we might observe the hiding power of the different formulas on the second and third coats.

SECOND COAT.

The weather conditions prevailing during the application of the second coat were practically the same as during the first coat, and the temperature was noted every day. A new can of paint was used for each test on the second coat, and the method of weighing used in the first coat was followed throughout. The contents of a fresh can of paint was placed into the enamel pot and thoroughly broken up. The consistency was then carefully noted, and one pint was used for reduction, this reduction being recorded on a separate sheet. The reduction was made with oil and turpentine, taking into consideration the formula and color of each

paint. The consistency of the reduced paint was taken and carefully noted upon the data sheet. The covering was noted at the time of application and marked down. The penetration and drying were noted every twenty-four hours. This coat was allowed about nine days to dry, with frequent inspection.

THIRD COAT.

A new package of paint was opened and the entire contents was poured into the enamel pot, and after being thoroughly broken up and mixed, was used as received, without reduction wherever possible, and where reduction was necessary, it was made and carefully noted. The same system of weighing was used in the third coat as on the first and second coats. The covering and working of the paint was carefully noted at the time of application, and inspection of the covering was made after the work was finished and the panel ready to be screwed to the fence. At this time glass slides of plain and orange glass, in frames, were placed on different panels.

LEADS. The leads were reduced by the ounce system, each ounce of vehicle added to $12\frac{1}{2}$ oz. of paste lead as received representing one gallon of vehicle to 100 lbs. lead. The amount of reduction was carefully noted, and the reduction compared with the consistency of the mixed paints used, thus giving a test throughout of equal conditions and applications.

GENERAL. This work was conducted in a large automobile garage, in the rear of a large hotel at Atlantic City, provided for this work. Benches and work tables and the proper accessories for this work were provided. The doors were locked and no one was allowed in the building except in the presence of the inspectors.

I believe this test to have been carried out in a practical and scientific manner and to the best of my knowledge will show interesting results, which will be of great benefit from

a technical standpoint. It has been my endeavor to do this work in a thorough and conscientious manner, and to treat everything with fairness to the best of my ability.

Thanking you for your confidence in my ability, I remain,
(Signed) J. B. CAMPBELL.

Wilmington, Delaware, March 16, 1908.

Mr. Robert S. Perry, Director,
Scientific Section,

Paint Manufacturers' Association of the U. S., Philadel-
phia, Pa.

DEAR SIR:—I have acted in the capacity of official in-
spector for Committee E, of the American Society for Test-
ing Materials, during the painting of the panels of the test
fence at Atlantic City, and have been present throughout
the work.

The work was carried on in a systematic manner, and the
treatment of the various paints and leads was made under
equal conditions, and in a careful and practical manner,
giving every panel and paint equal consideration. I have
endeavored, to the best of my ability, to see that everything
has been done in a fair manner, and I believe the experi-
ments will prove of great interest and benefit.

Mr. Campbell, inspector for the Paint Manufacturers'
Association, who had charge of the reduction, has worked
in a fair and conscientious manner, and no information
was given out by anyone connected with this work as to
the number of paint, or the number of the formulas. Every-
thing was kept under strict surveillance. Mr. Pablo, painter
for the Master Painters' Association of Philadelphia, and
Mr. Campbell were present with me throughout the work.
Hoping to be of further service, I am,

Very truly yours,

JAMES T. PARTHREE.

Philadelphia, March 16, 1908.

To Mr. Robert S. Perry, Director,
Scientific Section,

Paint Manufacturers' Association of the U. S., Philadel-
phia, Pa.

DEAR SIR:—I have acted as painter for Mr. Butler, who was appointed official painter of the Atlantic City Test Fence by the Master Painters' Association of Philadelphia, and have been present with Mr. Campbell and Mr. Parthree throughout the work.

I have been careful and conscientious in my work, and I believe that every endeavor was made on the part of every one connected with the work to treat all the paints and all the work with equal care and attention. The test was practical from every standpoint.

Hoping to be of further service, I am,

Very truly yours,

GEORGE PABLO.

To Mr. Robert S. Perry, Director,
Scientific Section,

Paint Manufacturers' Association of the U. S.

GENERAL REPORT OF PAINT TESTS MADE AT CARNEGIE TECHNICAL SCHOOLS, PITTSBURG, PA.

On January 30th, the work on the Pittsburg test fence was started. The weather was fairly good and the temperature was 50° F. inside the building where the paint was applied. The work was all done in the presence of the official inspector and weigher, Mr. C. D. Alexander, acting for Dr. James of the Carnegie Technical Schools; Mr. S. Ballinger, painter for Mr. A. C. Rapp, who was appointed official painter of the fence by the Master Painters' Association of Pittsburg, and myself, and was under the supervision of Mr. H. A. Gardner, chemist of the Scientific Section.

The panels were arranged in sets of six—first, two white

pine; second, two yellow pine; and third, two cypress—by Mr. Alexander, and in their proper sequence with regard to the consecutive numbers branded on these panels.

PAINTS. The various paints were received in quart cans labeled "Paint Manufacturers' Association," and the number of the paint contained therein, but with no information regarding the name of the manufacturer who prepared the paint or other directions or information regarding reduction, etc. The various white leads used were received in kegs of 12½ lbs. each.

BRUSHES. A heavy 7-0 round bristle brush was used for the priming coat, so that the paint could be thoroughly worked into the wood. On the second and third coats a three-inch flat chisel brush was used, and washed and cleaned thoroughly in two washes of turpentine after applying one number of paint on all six panels in one color. The painter then worked out all the paint from the brush and set the brush in pot No. 1, turpentine. The inspector then washed them thoroughly in pots Nos. 1 and 2, of turpentine, then dried them and handed them to me, and, after carefully noting that no pigment was left in the brushes, they were thoroughly worked into the next number of paint to be used. In this way no pigment was carried over from one paint to another.

SHELLACKING. Orange shellac was applied to knots on the bare wood of those panels used for paints Nos. 8 to 27, and over the priming coat on those panels used for paints Nos. 1 to 8. The shellac was applied by Mr. Ballinger and myself. By this method we have two conditions of shellacking from which we hope to draw inferences later on as to the best method of application. The shellacking on these panels was not so carefully done as on the Atlantic City fences, as I wish to determine for your satisfaction, whether some combinations would not stain or turn yellow or black more rapidly than others, also continue to stain to a greater area around the knot or sappy places. This information has been asked of me several times and I have not been able heretofore to answer same to my own satisfaction, and

I believe this will be a good demonstration of what we wish to determine.

PRIMING COAT.

A full quart can of paint as received was placed upon a correct set of balances and the gross weight was taken in grams and the weight of the paint as received was marked on the weighing sheets.

The can was then opened and the contents was poured into a half-gallon enamel pot and thoroughly broken up and stirred well to bring the mixture to thorough incorporation. The consistency was then noted and one-half of this paint was transferred to two half-pint friction top cans, which were sealed and marked with the number of the paint and name of the fence, and later on one set of these cans was sent to the Scientific Section, and the other sent to the laboratories of the Carnegie Technical Schools, for future reference and analysis.

Proper reduction was made for the priming coat of the balance of the paint in the enamel pot and it was then ready for application. The brush used for the priming coat was thoroughly worked into the paint and then the pot, paint and brush were placed upon the balance and the weight taken by the official weigher, in grams, using the metric system throughout in this test. The pot was then handed to the painter who applied the paint to one panel. After proper application, the brush, pot and paint were then handed back to the weigher and reweighed, the difference in weight being the weight of the paint in grams used on the panel, recording same on the weighing sheet, also the number of the panel upon which the paint was applied and the kind of lumber. This method of procedure was followed throughout the tests on every formula and on every panel.

The drying of the priming coat was noted every twenty-four hours on the different woods and the penetration was observed at the same time. The priming coat was allowed eight days to dry, and during this period inspection was made as to the drying.

At this period a black cross was stencilled upon the end of the middle board of each panel, with lampblack. This was placed there in order that we might observe the hiding power of the different formulas on the second and third coats.

SECOND COAT.

The weather conditions prevailing during the application of the second coat were practically the same as during the first, and the temperature was noted every day. A new can of paint was used for each test on the second coat, and the method of weighing used in the first coat was followed throughout. The contents of a fresh can of paint was placed into the enamel pot and thoroughly broken up. The consistency was then carefully noted and one pint was used for reduction, this reduction being recorded on a separate sheet. The reduction was made with oil and turpentine, taking into consideration the formula and color of each paint. The consistency of the reduced paint was taken and carefully noted upon the data sheet. The covering was noted at the time of application and marked down. The penetration and drying was noted every twenty-four hours. This coat was allowed about nine days to dry, with frequent inspection.

THIRD COAT.

A new package of paint was opened and the entire contents was poured into the enamel pot, and after being thoroughly broken up and mixed, was used as received, without reduction wherever possible, and where reduction was necessary it was made and carefully noted. The same system of weighing was used in the third coat as on the first and second coats. The covering and working of the paint was carefully noted at the time of application and inspection of the covering was made after the work was finished and the panel ready to be screwed to the fence. At this time

glass slides of plain and orange glass, in frames, were placed on different panels.

LEADS. The leads were reduced by the ounce system, each ounce of vehicle added to 12½ oz. of paste lead as received representing one gallon of vehicle to 100 lbs. lead. The amount of reduction was carefully noted, and the reduction compared with the consistency of the mixed paints used, thus giving a test throughout of equal conditions and applications.

GENERAL. This work was conducted in the basement of the Margaret Morrison Carnegie Building, provided for this work. Benches and work tables and the proper accessories for this work were provided. The doors were locked and no one was allowed in the building except in the presence of the inspectors.

I believe this test to have been carried out in a practical and scientific manner, and to the best of my knowledge will show interesting results, which will be of great benefit from a technical standpoint. It has been my endeavor to do this work in a thorough and conscientious manner, and to treat everything with fairness to the best of my ability.

Thanking you for your confidence in my ability, I remain,

J. B. CAMPBELL,
Inspector.

Pittsburg, Pa., April 1, 1908.

Mr. Robert S. Perry, Director,
Scientific Section,

Paint Manufacturers' Association of U. S., 3500 Gray's
Ferry road, Phila.

DEAR SIR:—I have acted in the capacity of official inspector for Dr. James, chairman of the committee appointed by the Carnegie Technical Schools, to supervise the painting tests which were carried on upon the school grounds and recently finished.

I was present with Mr. Campbell, inspector of the Paint Manufacturers' Association, and Mr. Ballinger, painter for

Mr. Rapp, who was appointed official painter of the fence by the Pittsburg branch of the Master Painters' Association, and was with these gentlemen throughout the work. This work was carried on in a most systematic manner, and the treatment of the various paints and leads was equally careful and unbiased in every way, and I believe that we all did our best to give every panel and every paint equal attention and consideration. The weighing, reductions, applications and drying were all observed with great care, and I wish to state that the work has been carried on in a fair and conscientious manner from start to finish.

No information was given out by anyone connected with this work as to the numbers of the paints or panels, and everything was kept under strict surveillance, the door of the shed, in which the work was carried on, being locked after working hours.

Very truly,

C. D. ALEXANDER.

Pittsburg, Pa., April 1, 1908.

Mr. Robert S. Perry, Director,

Scientific Section,

Paint Manufacturers' Association, 3500 Gray's Ferry road,
Phila.

DEAR SIR:—I have acted as painter for Mr. Rapp, who was appointed official painter of the Pittsburg test fence by the Master Painters' Association of Pittsburg, and I have been present with Mr. Campbell and Mr. Alexander throughout the work on the Pittsburg fence.

I have been careful and conscientious in my work, and I believe every endeavor was made on the part of all connected with the work to treat everything with equal care and attention.

Very truly yours,

SAMUEL BALLINGER.





DODGE & DAY
MUST BE RETURNED.

Preliminary Report

on

Steel Test Fences



**SCIENTIFIC SECTION
PAINT MANUFACTURERS' ASSOCIATION**

Preliminary Report

on

Steel Test Fences

SCIENTIFIC SECTION

PAINT MANUFACTURERS' ASSOCIATION

3500 GRAY'S FERRY ROAD

PHILADELPHIA, PA.

TO THE MEMBERS OF THE PAINT MANUFACTUR-
ERS' ASSOCIATION OF THE UNITED STATES

THE preliminary report on steel test fences, which is herewith presented to you, contains a general outline of the work which we have been conducting so arduously of late. A close study of this work will bring you in touch with the developments made in the new science of rust inhibition and will make more apparent the extreme importance of the tests which we have started.

Respectfully yours,

R. S. PERRY, *Director.*

November 20, 1908.

Preliminary Report on the Steel Test Fences

The completion of three new test fences at Atlantic City, N. J., should bring the manufacturers of protective coatings and the producers and users of metallic structural materials into closer touch with the principles involved and results looked for in the test. A brief description of the work leading up to these tests and their importance to the manufacturer and user of the raw materials represented therein is herewith given.

Nature of Pigments—Stimulators

The investigations by Dr. Allerton S. Cushman, of the principles underlying the corrosion of iron and the effect of certain materials in preventing this corrosion, have lead to an immense amount of research work upon this subject. The question of the possible value of chromic acid compounds as protectives of steel, and the proper application of these compounds, became a subject of such great import that the Scientific Section considered it advisable to make extensive and practical tests for the benefit of the Association. From the tests conducted by Dr. Cushman to determine the effect which all the well-known pigments have upon steel, he has concluded that some were entirely unsafe to use in a paint designed for the protection of steel. These pigments have been classified as Stimulators of Corrosion.

Inhibitives

Other pigments in his test indicated remarkable properties of protecting steel from corrosion, and were termed Inhibitives to differentiate them from the other types of pigments.

Indeterminates

Still other pigments were found to fall within another area, and, as another class or type, were called Indeterminates because of the neutral zone in which they fall, neither stimulating nor inhibiting corrosion to any marked degree.

Effect of Impurities

It is true that certain impurities incidental to the manufacture of certain pigments can be held to account for the action of such pigments, and will determine in which group these pigments will be placed. It has been found that in the manufacture of certain pigments minute traces of impurities are included in the particles as they are precipitated from solution, and their nature precludes the possibility of absolute removal by washing. These minute traces have either rust stimulating or inhibiting action, according to their nature. It has been discovered that

certain pigments, for instance the group of blues generally designated as Prussian blues, may be prepared in two different manners and from the same basic raw materials, and each will contain small traces of different impurities. These infinitesimal amounts of impurities have proven themselves, according to tests made with the Thompson-Cushman apparatus, capable of either exciting electrical action and causing subsequent oxidation of the metal or they have proven equal to the task of preventing corrosion through their nature and composition. Unfortunately, it is impossible for the analyst or even the expert color maker to differentiate between the two blues, as both would render upon examination, because of the infinitesimal amounts of impurities contained within, the same identical analysis, and they would both show the same tint, tone, and strength.

Immunization and Infection

However, the property of certain chemically pure pigments of immunizing iron from rust has been attributed to the property possessed by these pigments of rendering negative to electrolysis the steel with which they come in contact. Other chemically pure pigments have been found by Dr. Cushman to possess the property of electrically exciting steel and causing extremely rapid corrosion, or infection, if one prefers to put it that way; this being exactly what might be expected or even demanded of these materials when used in other arts, such, for instance, as the development or use of electrical energy.

Field Test Committee

For the practical testing out of these materials as paint products, the Scientific Section proposed the erection of fences having several hundred large steel plates upon which to try out the value of the different pigments when contained within an oil medium. The American Society for Testing Materials was notified of this project, and at a meeting of Committees "E" and "U" it was decided to co-operate in supervising and inspecting the work; satisfactory specifications to be prepared and adopted by these committees. The joint committee appointed to carry on the work consisted of the following personnel:

Dr. A. S. Cushman, Asst. Director, Office of Public Roads, U. S. Dept. of Agriculture; Chairman Committee "U," American Society for Testing Materials.

Mr. P. H. Walker, Chief, Contracts Laboratory, Bureau of Chemistry, U. S. Dept. of Agriculture.

Dr. Wm. H. Walker, Professor of Industrial Chemistry, Massachusetts Institute of Technology.



A SIDE VIEW OF STEEL TEST FENCES

Mr. S. S. Voorhees, Engineer of Tests, Office of Supervising Architect, Treasury Department; Chairman Committee "E," American Society for Testing Materials.

Mr. Gustave W. Thompson, Chemist, National Lead Co., Brooklyn, N. Y.

Mr. G. B. Heckel, Secretary, Paint Manufacturers' Association of the United States.

Mr. H. A. Gardner, Asst. Director, Scientific Section, Paint Manufacturers' Association of the United States.

These gentlemen, all of whom are members of the American Society for Testing Materials, have been closely associated with the testing out of raw materials used in the manufacture of paint; in conducting field exposure tests, and in studying the subject of the corrosion of iron.

Previous to the erection of the fences it was thought advisable to parallel the tests made by Dr. Cushman, and a quantity of nearly every well-known pigment was secured for the purpose. Samples of each pigment, out of the same batch, were forwarded to the various members of the committee and tested for a period of three weeks in the Thompson apparatus as modified by Dr. Cushman.

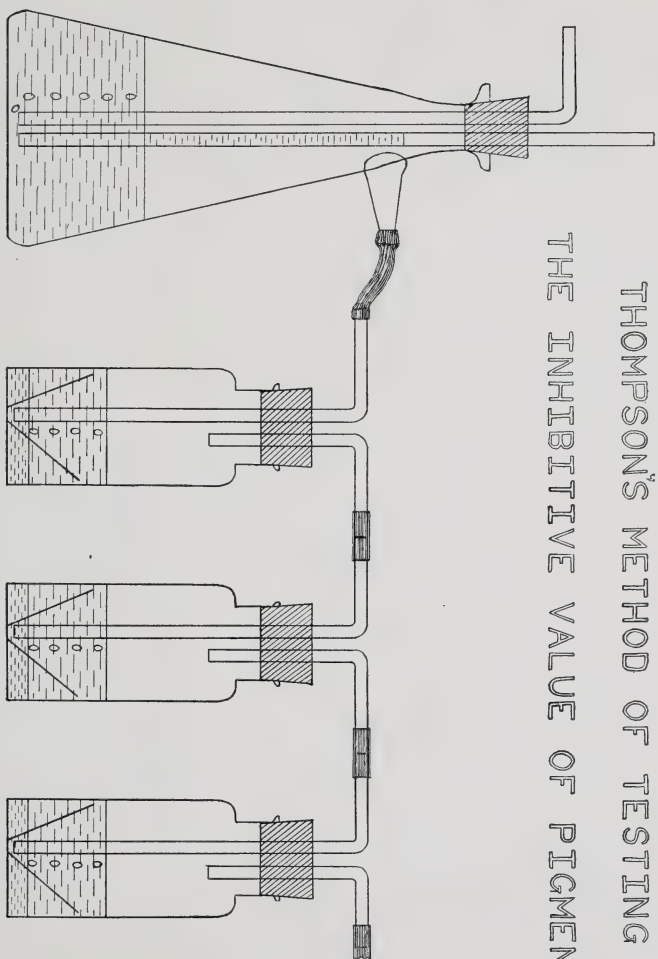
Laboratory Method of Testing Pigments for their Inhibitive Effect

In this test, a series of four-ounce bottles are arranged as in the illustration. Into each bottle is placed 100 c. c. of distilled water and there is added to the bottles in succession an equal amount by volume, 10 c. c., of the various dry pigments to be tested.

Carefully weighed steel plates are inserted in each bottle and at the end, middle and beginning of the train of bottles, blanks are inserted. By means of the pressure bottle at the beginning of the train, a fairly constant rapid current of washed air is conducted through the train for a period of three weeks. The position of the bottles in the train may be changed daily if so desired. At the end of the period the plates are removed from the bottles and the extraneous pigment carefully washed off. The plates are then thoroughly cleansed in distilled water, washed in ether, dried and reweighed to determine the amount of iron that has been lost through corrosion.

The results obtained by the different investigators, working independently, but in the same manner and with the same apparatus, were compared at a meeting held in the government laboratories at Washington on September 15th, and it was found that the results coincided very closely with the original results obtained by Dr. Cushman.

THOMPSON'S METHOD OF TESTING
THE INHIBITIVE VALUE OF PIGMENTS.



The pigments were then divided into three groups, according to their effect upon the steel plates, and termed either inhibitives, indeterminates, or stimulators.

Pigments Tested

The following pigments were tested out, but in this list are placed regardless of their action on steel.

Calcium Carbonate (Whiting).

Precipitated Calcium Carbonate.

Orange Chrome Yellow.

Medium Chrome Yellow.

Lemon Chrome Yellow.

Calcium Sulphate.

Chrome Green, Blue Tone.

Chrome Green, Yellow Tone.

Prince's Metallic Brown.

Orange Mineral French.

Orange Mineral American.

Graphite I.

Graphite II.

Dutch Process White Lead.

Quick Process White Lead.

Zinc Oxide.

Sublimed Lead.

Sublimed Blue Lead.

Zinc Lead White.

Black Magnetic Oxide.

Zinc and Lead Chromate.

Neutral Prussian Blue.

Stimulative Prussian Blue.

Inhibitive Prussian Blue.

Ultramarine Blue.

Naples Yellow.

Carbonith White.

Barium Chromate.

Zinc Chromate.

Zinc and Barium Chromate.

China Clay.

Asbestine.

American Vermilion.

Red Lead.

Litharge.

Bone Black.
Lamp Black.
Willow Charcoal.
Carbon Black.
Mineral Black.
Keystone Filler.
Bright Red Oxide.
Indian Red.
Venetian Red.
Lithopone.
Barytes.
Precipitated Blanc Fixe.
Ochre.
Sienna.
Umber.

Field Tests

The majority of these same pigments enumerated above and tested out, as above described, were then prepared for the field test.

Preparation of Formulas

The preparation of the formulas for the paint to be used in the field test involved the taking of the specific gravity of the various pigments and when this was accomplished a definite formula for the grinding was decided upon so that the same amount by volume of each pigment would be used in the same quality of oil. It was decided to grind these pigments separately, in a mixture of two-thirds raw and one-third boiled linseed oil, no drier being included because of the unknown factor which would be introduced by the lead content of such drier. Besides the pigments ground separately in oil, a series of special paints was made. These paints were designed to show the difference between the inhibitive and the stimulative type of paint. Several of these paints, which were termed inhibitive paints, were made of the most inhibitive pigments which our preliminary laboratory tests had given us. Another set of paints, termed stimulative paints, was made of several of the most stimulative pigments which our laboratory tests had shown.

Selection of Steel for Test

The protection of steel and iron surfaces has been considered by some to be entirely a question of proper preservative coatings, but the recent investigations of Dr. Cushman into the causes of corrosion developed the fact that electrical action and rusting, other things being equal, are most ardent in iron having an uneven distribution of impurities. The

nature of the impurities and the difference in potential of the impurities, to that of the iron, has been another cause of the rapid oxidation of this metal. With these facts in view, the committee decided to make the tests on three classes of metal: ordinary low-carbon Bessemer steel, normal structural steel, and pure iron.

After a discard of twenty-five per cent. had been made from the billet of Bessemer steel rolled for the test by the American Sheet & Tin Plate Co., an analysis showed the presence of the following:

Carbon .....	.08
Manganese .....	.35
Phosphorous .....	.08
Sulphur .....	.05

The structural steel made by the Carnegie Steel Co. for the test contained the following:

Carbon .....	.16
Manganese .....	.44
Phosphorous .....	.02
Sulphur .....	.024

The pure iron, which was furnished by the American Rolling Mill Co., gave the following analysis:

Sulphur .....	.024
Phosphorous .....	.055
Carbon .....	.03
Manganese	Trace
Silicon	Trace

It is not the object of these tests to distinguish the resistance to corrosion of various types of metal, but in view of the variation in resistance which is known to exist, the committee thought the pigment tests would be strengthened by using several different metals.

It is very desirable to be able to place full confidence in the conclusions and deductions to be drawn from the tests on these steel plates, and the determination of the relative rust inhibitive values of these various pigments will be emphasized with greater certainty by the use of three grades of steel.

It is apparent that if these three grades of steel have each a different tendency toward corrosion with any one given paint material applied to the surface, all other factors and conditions being absolutely constant, we then obtain a better measure of the qualities of our paint materials in their disposition to either prevent or stimulate corrosion.

For example, if pigment A, on any one given grade of steel, shows



FRONT VIEW OF STEEL TEST FENCES

somewhat better inhibiting qualities than pigment B on the same grade of steel, the difference might be such that a conservative mind would hesitate to judge between pigment A and pigment B.

If, however, pigment A on all three grades of steel shows less tendency toward corrosion or better rust inhibiting qualities than pigment B when applied to each of the same grades of steel, the three verdicts in favor of pigment A would be much more conclusive than if only one grade of steel was used. The practical man in drawing his conclusions could then rest assured of their reliability if the steel with the greatest tendency to corrode would show better results when protected by pigment A than the steel with the least tendency to corrode when used with pigment B, and the verdict would safely be in favor of pigment A on all three counts.

Several hundred plates were obtained from the manufacturers and one-half the number chosen for the test were pickled in sulphuric acid, then neutralized with soda ash, thoroughly washed, and preserved from future oxidation in dry lime until needed for the test. The removal of the mill scale was complete in the case of the pickled plates and a perfectly clean, neutral surface was obtained upon which to apply the paints.

Painting of Plates

The painting of the plates was done under cover in a temporary building erected for the purpose. This was necessary in order to have uniform conditions for the application of each formula. A definite spreading rate of nine hundred square feet to the gallon was used on the paints applied to the cleaned plates, while the paint applied to the black plates, *i. e.*, those not pickled and having the ordinary black mill scale, had no definite spreading rate. The paint was applied under the constant supervision of the Director of Tests, by the painters representing the committee and the Master Painters' Association. Three-coat work was used throughout on the cleaned plates upon which the original fifty-one pigments were applied, but in some cases, on the black plates, where the special formulæ was applied, two-coat work was used, all of this data being included in the report of the work. A page from this report will explain the detail and care with which the work was undertaken.

No. of Pigment	Name of Pigment
Applied to 6 plates, 2 feet x 3 feet.	
Spreading rate 900 square feet per gallon.	
Sp. Gr. of Pigment	6.45
Lbs. to Gallon Oil	19.17
Sp. Gr. of Paint as Recd.	2.36

Wt. of Paint per Gallon	19.65
Grams to Panel	59
Condition of Paint	Good
Working Properties	Heavy
Drying	Good

- 1 Coat Oct. 27 T 60 B 32.1 W fair*
- 2 Coat Nov. 4 T 60 B 31.3 W clear
- 3 Coat Nov. 11 T 56 B 30.2 W cloudy

Details of Application

After the specific gravity of the paint had been taken and the amount necessary for the application to each panel had been reckoned according to the spreading rate, a quart of paint was placed in a half-gallon enameled cup, and stirred well to bring the mixture to thorough incorporation. A brush was thoroughly worked into the paint, and pot and all was placed upon the balance and the weight taken in grams, using the metric system throughout the test. The pot was then handed to the painter who applied the paint to one plate. The number of grams applied to each panel was deducted from the counter-balance and when the pot, paint and brush exactly balanced, the panel was cross-brushed and laid out. The final weighing was then made to see that the counter-balance was maintained. The plates during the work were set upon a frame resting upon a bench, room being allowed beneath the plate for the painter to place his hands beneath the plate to lift it after the brushing had been finished. The plate was then taken from the bench and slid into a specially prepared rack, so that the paint would dry in a horizontal position. Racks for several hundred of these plates were built and used during the test.

A sufficient length of time between the coats was allowed for the thorough drying of each pigment. Extreme care was used in painting the edges of the plates, for the reason that corrosion generally starts at this point of attack. Each pigment was applied in duplicate to each class of steel, so that when set upon the fence they could be placed in both an Eastern and Western exposure. The working properties of the paint were carefully noted and wherever it was found that the consistency of the paints developed brush marks, these points were included in the report. The brushing of the various pigments and other features observed during the test were also noted, and considerable data was ob-

* T stands for temperature (F.).

B stands for barometer.

W stands for weather.

tained upon the working of the various pigments. The temperature and weather and height of the barometer were also included in the report, as the above page will show.

No reductions were made to any of the paints applied except in one or two cases, where the viscosity of the paint was so great that the possibility of brushing was precluded. A small amount of turpentine was added in these cases and the amount of paint to be applied to the panel proportionately increased so that when the turpentine evaporated the amount of paint originally intended, would be upon the plate.

Priming Coat with Inhibitives

The use of the inhibitive pigments, as priming coats for steel, was considered in this test, and several plates were first-coated with the most inhibitive pigments and then second-coated with a good excluding paint. These tests included plates prime-coated with red lead and other materials which in the past have been so largely used on structural steel work, and then given a top coat of the same excluding paint that was used in the other test.

Fences and Setting Up of Plates

Method of Securing Plates to Fence

The fences upon which the steel plates were fastened after the painting are three in number, and each one is one hundred and twenty feet long and five feet high. They are built of yellow pine studding, four by four, the posts being set eight feet apart and strongly counter-braced underneath the surface of the ground with two-by-fours. A strip of two-inch batton is provided along the lower beam on either side of each fence, as a resting place for the plates. The plates rest on two small pieces of raw hide fastened eighteen inches apart on the battons, thus being raised a sufficient distance from the batton to prevent the accumulation of water at the bottom of the plates. The plates rest and back against the beams at top and bottom, and are fastened to these beams by metal buttons screwed into the wood between and lapping over an equal distance on two plates. Insulation of the buttons was obtained by the interposing of rubber strips between the plates and the button. The buttons were enameled and the screw heads painted and subsequently plugged with putty. This method of fastening the plates obviates the bad practice of drilling screw holes through the plates which invariably starts a place of corrosion. Each plate has lettered upon its lower left-hand corner the number of the paint or pigment with which it is painted, and a numeral to show the class of steel used. Below each plate, in order to secure permanent identification, these same numbers are

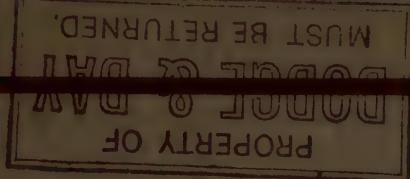
stamped in the wooden fence. The back of each plate is primed with a good varnish paint in order to prevent rapid corrosion.

Unpainted Plates Tested Future Value of Tests

A glance down the avenue of panels gives a very pretty illustration of the color, shade, opacity, or transparency in oil, and other properties of the various pigments represented on the panels. On certain pigments, the hiding properties of which are slight when contained within an oil medium, the clean surface of the metal can be visibly observed even through the three coats of paint. It is evident that the start and growth of corrosion on such plates could be watched very closely and would afford a very clear illustration of the progress of rust. A few extra plates of special Bessemer steel and pure Swedish charcoal iron are included in the test and are to be identified by special numbers. A few plates, both cleaned and black, of each class of steel tested, were placed upon the fence without any coating, in order to observe the relative amount of corrosion which these plates will develop without such coating. The rusting of iron is accelerated by the presence of salt atmosphere, and, for that reason, these tests, being located in Atlantic City, N. J., will afford within a comparatively short time some interesting information, both for the chemist and practical paint manufacturer. The architect and the engineer, the mechanic and the painter, and every technical man who recognizes the necessity of information such as will be derived in this way, should watch this test very closely, and the conclusions which the committees, after their various inspections, arrive at, should lead to the production of preservative coatings that will do more for the building industry than ever before has been accomplished along these lines of experiment.

H. A. GARDNER, *Director of Tests.*

N. B.—Messrs. Butler, Ebey, Parthree and Sands are to be thanked for their co-operation in the Field Work.



**RECENT
TECHNICAL
DEVELOPMENTS
IN
PAINT
MANUFACTURE**



**SCIENTIFIC SECTION
PAINT MANUFACTURERS' ASSOCIATION
3800 GRAYS FERRY ROAD
PHILADELPHIA, PA.**

Recent Technical Developments in Paint Manufacture

“The Knowledge to be Obtained by the
Master Painter from the Test Fence
Proposition.” By R. S. Perry

“Composite Base Paint and Its Benefits
to the Master Painter.” By F. A. Lane

Discussion

WITH ACKNOWLEDGEMENTS TO
AND FROM THE PROCEEDINGS OF
THE PENNSYLVANIA ASSOCIATION OF MASTER
HOUSE PAINTERS AND DECORATORS

Reading, Pa., January 12, 13, 14, 1909

Published by the
Scientific Section Paint Manufacturers'
Association of the United States

3500 Grays Ferry Road
PHILADELPHIA, PA.

PREFACE

Certain important discoveries having been made in the laboratories of the Scientific Section, which strongly emphasize the necessity of using pigments of three or more determinate sizes in a paint coating, it is advisable that the manufacturers of paint should have full knowledge on this subject. A series of experiments are described in the following paper entitled "The Knowledge to Be Obtained by the Master Painter from the Test Fence Proposition," read before the Master House Painters' and Decorators' Association of Pennsylvania at their Twenty-First Annual Convention, held in Reading, January 12, 1909. These above-mentioned tests confirm the original deductions made by the writer in his address before the Michigan Chapter of Architects in 1907.

The practical paper read by Mr. Frank Lane, on the subject of "Composite Base Paint and Its Benefits to the Master Painter," at the same meeting, is also printed herein as a closely related subject. Mr. Lane's paper bears out the scientific facts which are given in the paper on test fences and also gives the latest developments in Composite Base Paint, from the standpoint both of a practical master painter and the factory superintendent. It seems proper to publish together at this time the scientific and practical proofs of the necessity for using a blend of pigments and also the latest word about such a combination in Composite Base Paint. The discussion which followed the reading of these two papers is included in this publication, both because fair play seems to require that the protest against the new composite base in oil, as made by Dr. G. W. Thompson of the National Lead Company, should be stated and also to give those interested in the use of a blend of pigments an opportunity to correct some of the objections which have been made.

R. S. PERRY,
Director Scientific Section.

INTRODUCTION

The Scientific Section has performed a valuable service in this publication, which lays before the members of the Association and the public, in convenient form, a record of one of the most remarkable and enlightening sessions ever held by a Master Painters' Association. While the discussion turned, as will be seen, largely upon the theory of Composite Base Paints, the addresses themselves, together with the discussion, involved the entire question of paint manufacturing economics and progress. Every word uttered in the discussion was carefully considered and a reading of the report will show that paint manufacturers have everything to hope from a better understanding and franker relation with progressive master painters.

This pamphlet is heartily commended as a practical working document to manufacturers, sellers and users of paints. It illustrates, as nothing heretofore published has illustrated, the immense advance made in our knowledge of the factors governing value and efficiency of the paint coating.

Certain points in the discussion may be elucidated by reference to facts not available for use on the floor of the Convention.

Much of the work discussed herein represents an invasion of new fields of investigation. For example, Mr. Perry's beautiful demonstration of the relative permeability of paint films is, to all interests and purposes, an absolutely fresh contribution to paint technology. It suggests a line of investigation that cannot fail to throw a new light upon the subject. It goes strongly to confirm the contention that the manufacturers of high grade paints are on the road of progress and that this progress has come none too soon to meet the demands of new conditions and an ever increasing discernment on the part of those who control the practical application of painting materials.

The temper of the Convention—a body of painters as intelligent as could be collected in this country—was distinctly friendly. The papers

were listened to with close attention and the comments which followed their reading evidence an intelligent appreciation of the work described and its bearing upon the interests of the craft.

The entire pamphlet is heartily commended to the attention of the paint trade in general, and to the members of the Association in particular.

G. B. HECKEL,
Secretary Paint Manufacturers' Association of the U. S.

THIRD DAY—MORNING SESSION

(Thursday, January 14, 1909.)

PRESIDENT RAPP:—We will receive some words of explanation on the subject: "The knowledge to be obtained by the master painter from the test fence proposition." The test fence proposition is a proposition gotten up by the Paint Manufacturers' Association of the United States for testing out various formulas as they may be conceived by different manufactures, and including what they consider the best formulas to make the best paints.

These test fences have been erected at Atlantic City, Pittsburg and in North Dakota, the Atlantic City fence being subject to the salt and moisture of the coast, the Pittsburg fence to the different climatic conditions there, where they meet the sulphurous gases, and the one in North Dakota subject to the dry climate of the west. The fence proposition is one that is very important to those interested in paint. Mr. Robert S. Perry, Director of the Scientific Section of The Paint Manufacturers' Association of the United States, has this matter in charge, and I consider him the best man to speak to you about the proposition.

Gentlemen, I take great pleasure in introducing to you, Mr. Robert S. Perry, Director of the Scientific Section of The Paint Manufacturers' Association of the United States. (Applause.)

MR. PERRY:—I want to say there is a great deal of sentiment in me in regard to this meeting to-day. I want you gentlemen to know that it is particularly fitting, because the first time I addressed anybody on this subject was in a meeting of your State Association. It was in the State of Pennsylvania that the idea of a scientific section first received its impetus—its first suggestion—from some of you master painters, and it is due to you that the scientific section is in existence to-day.

I also want to say to you, if it had not been for the co-operation of some of the master painters in this room, the co-operation of master painters of a high type of integrity, with their practical knowledge, that

I believe, gentlemen, the testing of paints on these fences would be practically without value. A practical and skillful application of the paint under the brush is to you, gentlemen, two-thirds of the game. The question of uniformity of application of the paints is of extreme importance in these tests.

“THE KNOWLEDGE TO BE OBTAINED BY THE MASTER PAINTER FROM THE TEST FENCE PROPOSITION”

By R. S. PERRY.

*Mr. President and Members of the Penna Association
of Master House Painters and Decorators:*

The manufacturer, the master painter and the property owner are all interested to-day, as never before, in the subject of paint.

The progressive paint manufacturer is making great effort to put the art of paint manufacture, as far as possible, under the control of exact science.

The master painter is determined to learn more about the composition of the various paint products and to know what characteristic properties are given to a paint by this or that raw material; in other words, he insists upon having fuller knowledge and data about paint, so that he, as a master, may use his best judgment and discretion in selecting his material and in procuring more beautiful and durable results.

The property owner desires further knowledge of this subject, in order that his property may be protected for as long a period as possible when he invests his money in a coating of paint.

Both, the master painter and the property owner, to-day clearly appreciate the fact that the total cost of the paint itself is only from one-third to one-fourth of the cost of the final protective coating, including labor and material, and that too much care cannot be taken in choosing the material, because the other three-fourths of the investment, namely, the labor cost, may be rendered valueless by the use of an adulterated paint or one prepared after a poorly balanced formula.

Master Painter
Seeks Knowledge
of Raw Materials
and Formulas

Property Owner
Equally Desirous
of Data

Comparative
Cost of Material
and Labor in a
Paint Job

There is, therefore, every reason why the manufacturer who produces, the master painter who applies, and the property owner who finally owns and pays for the coating of paint—why all three of them should discuss together the prime or first principles of what a paint must do and why certain laws must be observed in compounding it.

**Service Required
of a Paint**

Let us, then, first consider the service which a paint has to perform when applied as a protective coating. In discussing the conditions, it is proper to take the most severe service and that for which paint is most largely used. We will, therefore, confine ourselves to paint used out of doors to protect lumber in the form of structural material, whether the lumber be in a house or in some other structure.

**What a
Paint Coating
Does**

The average paint coating is only three one-thousandths of an inch thick, and yet this thin coating is required to withstand expansion and contraction of the underlying surface, abrasion or wear from storms, of dust and sand; or rain, sleet and hail. It must have both hardness to withstand to a reasonable extent this surface wear, and yet enough elasticity to meet internal strain and to conform to changes in the underlying surface, and it must penetrate and cling to the surface upon which it is applied. It must also retard or prevent from access to the underlying surface; both the moisture and atmospheric gases which cause decay.

**Lumber and Its
Physiology**

Let us consider the nature of the materials upon which the paint is to be applied, namely, the lumber itself. Lumber is a product of animate nature, that is, it has, in common with all other living structures, skeleton or cellular tissue, flesh or gelatinous material in the cells of the wood, and life-blood or sap.

Timber vs. Lumber

We know that when the growing timber is converted into lumber, that is to say, with the death of the wood, there is an immediate tendency to putrefaction or decay, and that the great agencies of such decay are air and moisture, together with the products they bear, and the

circulating fluid or sap of the timber, which remains in the lumber after death.

The merchant, therefore, kiln dries his lumber to eliminate, as far as possible, the sap and moisture as agencies of decay.

From that time forward, the chief agency to decay the lumber is moisture, whether the moisture is brought to the surface of the lumber and introduced into its cells through the gases of the air or in actual visible form, that is, as liquid water.

Cause of
Decay of Lumber

Human experience has thus far found a paint coating the best barrier to exclude these agencies of decay, liquid water and the gases of the air. Paint to produce this coating is usually composed of linseed oil, a semi-liquid known as the vehicle, containing necessary thinners and driers, and small particles of solid matter suspended in the oil, known as the pigment.

Paint,
the Great
Arrester of Decay

The painter spreads this paint as a thin film under his brush, and this film, by the action of the oxygen in the air, hardens into a coating composed of semi-solid linoxyn or dried linseed oil containing the small particles of pigment.

This paint coating of linoxyn and pigment has remarkable elasticity, so that it will conform to shrinkage or swelling of the underlying material and will adapt itself to strains within the mass of the actual coating itself, and to exterior or outside physical violence, while the pigments give to this soft and otherwise rather perishable linoxyn the indispensable properties of solid matter necessary to preserve the life of the paint coating.

Elasticity and
Hardness of Surface
Necessary in a
Paint Coating

This summarizes, roughly, what human experience has selected for a protective coating to protect structural lumber under conditions of outdoor exposure.

The lumber, however, was originally endowed with life and a product of animate nature, and it is well that we should go to school to living nature to ascertain what provisions she has made to protect the life of living structure.

When a tree is injured, the life-blood, or circulating fluid, in the form of sap, immediately pours out to protect the wound.

This vegetable fluid, or sap, forms a thin film over the wound, just as the painter spreads his coating of oil over the dead lumber, and then, by the action of the air, this semi-liquid sap is hardened to a semi-solid film, or gum, which is startlingly like the coat of linoxyn.

The tree is endowed with life and can, by gradual growth, repair the wound thus temporarily closed. Therefore, the paint coating of living nature need not be very durable. The dead lumber, on the other hand, requires a more durable protection, and both the master painter and the property owner desire a maximum life for the coating of paint, so that they may obtain the greatest value from the investment of their time and money.

We have thus seen that human experience has unconsciously gone to linseed oil, itself originally the vegetable sap, or life-blood, of a living structure, and that human ingenuity has thus copied nature in producing the coating of linoxyn.

The linoxyn, or dried oil, alone is seen to be porous, soft and perishable.

Human experience has sought to meet the second problem, that of permanency, by the addition of particles of pigment to the body of the paint, to give greater solidity, durability and to sufficiently fill the pores or voids.

The conscientious paint manufacturer surely knows to-day that to get the best product he must make use of every available bit of technical knowledge and of past experience in the compounding of his formula, and that if he is to do his duty by the painter and the property owner, his paint formula should contain more than one size of pigment particle, generally necessitating that the paint be composed of more than one pigment.

In choosing our pigments, we have very little guidance

from nature and must turn to the testing laboratory and the school of experience for guidance. What pigments shall we choose and in what proportion to leave to the coating of linoxyn a necessary and reasonable amount of elasticity, and yet produce the greatest permanence?

**Nature of Pigments
to be Considered**

Up to our present generation, white lead and the mineral oxides were the pigments almost universally used.

At the present time these materials have not lost their value and are recognized and used as the principal pigments in compounding many formulae, but to-day the paint manufacturer realizes that his experience and the data which his chemists and technical laboratories have put at his disposal make it imperative that he should use reasonable amounts of other materials in his paints, in order to further strengthen them and to supply certain properties in which white lead and mineral oxides are deficient.

**Value of
White Lead and
Natural Iron
Oxides**

Unfortunately, the paint manufacturer has not in the past worked out his problems in sympathy with and with the help of the master painter. The paint manufacturer necessarily eliminated much detail of work in the shop of the master painter, and, while the master painter was, perhaps, influenced by this and other causes to antagonize his products, on the other hand, the paint manufacturer yielded to the temptation of eliminating the necessary skill of the master painter, and, in some cases, put his product directly under the brush held by an ignorant hand.

**Aid of
Master Painter
Necessary in the
Improvement of
Paints**

Let the past history be what it may, it is most encouraging that to-day the paint manufacturer is seeking to discover the particular needs of the master painter, and that the paint manufacturer to-day recognizes that the metropolitan master painter requires a material other than ready-mixed paint, ready to apply and must be given a product more available and adaptable to the varying conditions which he is forced to meet on the job.

It is also very encouraging that the master painter insists upon knowing more about paint products and is

eager to learn the latest discoveries in technical science, which may improve the products available to his art and craft.

**Work of
Scientific Section**

The Scientific Section of the Paint Manufacturers' Association of the United States, in its practical field tests and in its laboratory investigations is endeavoring to give to the master painter the benefit of the scientific work which is being done.

The first basic question to be asked by the master painter and to which he must be given a satisfactory answer, is, Why should more than one pigment be used in a paint?

**Number of
Pigments Used and
Consistency or
Proportion of
Vehicle**

If it can be shown that more than one pigment must be used to produce the best results, then both the manufacturer and the master painter are in a position to take up the second problem of the consistency of the material and the shape in which it is to be produced to suit the necessities of the work, in other words, problems such as Composite Base Paint.

It is not intended here to enter into a discussion of the merits of Composite Base Paint or a demonstration in favor of a mixture or composition of any particular set of pigments for the base of paint, but it is intended to show the essential nature of a paint and the reason why more than one pigment should be used.

**Relation of
Pigments to Density
and Durability of
Paint**

In addresses before the American Institute of Architects, at Detroit, and before the American Society for Testing Materials, both in 1906, the writer, by scientific deduction, suggested as a scientific law, that pigment particles of two or more determinate or characteristic sizes must be used to give a paint proper density and durability, that the particles of pigment must be of several sizes to fill the voids properly.

To-day it is possible to prove and confirm this law by a simple yet striking experiment.

We can first demonstrate that a film of dried vegetable sap or oil, such as linseed oil, which the chemist calls linoxyn, is filled with what the cement expert calls



Bell Jar Apparatus for Testing Permeability of Paint Films

Experiment
to Prove a
Paint Film of
Composite Pigments
is Less Porous than
a Single Pigment

“voids” and is porous, and the following table will show the rapidity with which carbonic acid gas actually passes through such films of linoxyn with various pigments incorporated or ground into the oil. Taking the porosity of a film of oil and asbestine as 100 per cent., on two hours’ treatment we find as follows:

Porosity of Asbestine film	100.00%
Porosity of Corroded white lead film	89.10%
Porosity of a high grade Composite base paint film containing white lead, asbes- tine and zinc oxide	71.00%

Again taking the porosity of Zinc Oxide at 100%, we find as follows:

Porosity of film of Zinc Oxide.....	100.00%
Porosity of film of Zinc Oxide and a small quantity of Barytes.....	58.00%
Porosity of film of Zinc Oxide and small quantities of Barytes and Blanc Fixé,	54.00%



Bottles Showing Relative Permeability of Films by Amount of Whiting Formed Within

Now, let a number of films of linoxyn be prepared, the first containing, say, one pigment, such as barytes,

another containing two pigments, such as barytes and blanc fixe, and a third film, carrying three pigments of different sized particles, for instance, barytes, blanc fixe and zinc oxide; let these films be used as covers or seals for as many glass receptacles.

Let us place in these glass receptacles, previous to sealing, a reagent or chemical which will absorb carbonic acid gas and fix it chemically in such a way that we can measure or weigh it. Ordinary lime water, which can be purchased in any drug store, will do this, and will form, with the carbonic acid gas, calcium carbonate, or common whiting.

If these receptacles be now placed in a tight room or container filled with carbonic acid gas at somewhat above atmospheric pressure and so that the gas is pressing equally on each skin, it is evident that we can measure the relative porosity or sponginess of each film by the amount of gas which it allows to pass through from the outside into the container which it seals. Thus we obtain a comparative measure of the effectiveness of any pigment or group of pigments taken to close the pores or voids which have been mentioned as existing naturally in the linnoxyn itself. The average results obtained from a number of such experiments show that beyond all question pure linnoxyn without pigments is extremely porous. It is also shown that a paint must have pigments in it; that one pigment does part of the work of filling the voids; that two do more of the work; but that, if three or more pigments of different sized particles are used to make the paint, we get much better excluding values and go a great step forward in making the paint skin sufficiently impervious to gas. Similar experiments yield the same result with regard to moisture.

In the pigments chosen, the size of particles varied greatly. Barytes particles are naturally large, while blanc fixe is of medium fineness and zinc oxide about the finest pigment we know of. It is of interest to note that white lead by itself, because of the great variation of its par-

**Porosity of Films
Relative to
Size of Voids**

ticles, comes more nearly to filling the necessities of the paint coating than any one other pigment alone, but white lead alone does not fill the pores or voids sufficiently.

Laws on Concrete
Apply in
Making Paints

This work thus proves that exactly the same law obtains in making a paint coating which is a sufficient water-proof or excluder of agencies of decay, that exists in making a good concrete. No one would attempt to-day to make a good concrete out of one material, such as the sand alone or the broken rock alone, with the liquid vehicle of water and cement.

This same experiment on films of corroded white lead and of Composite Base Paint conclusively demonstrated the superior excluding and void-filling values of the Composite Base Paint.

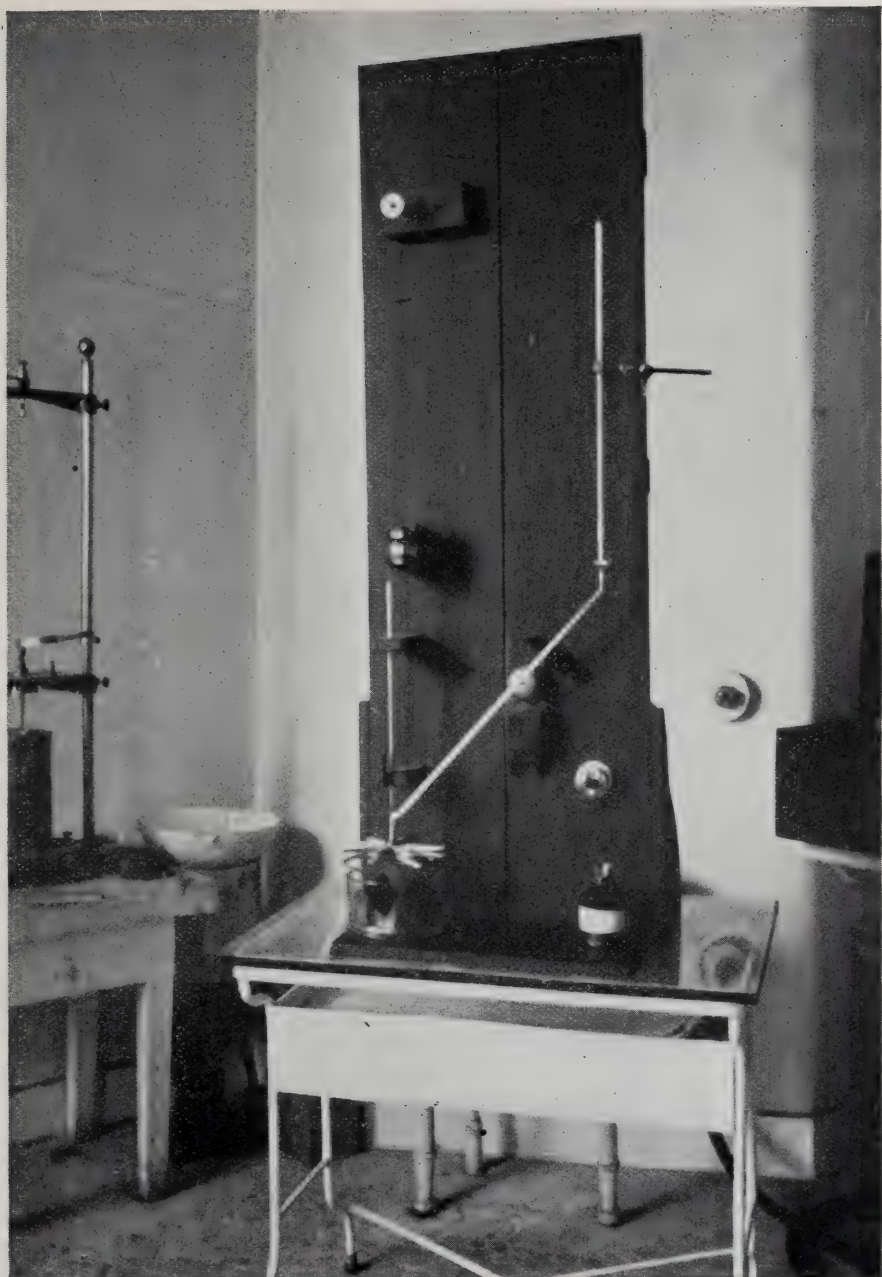
Superior
Excluding Values
of Composite
Base Paints

Having thus shown and demonstrated by experiment with carbonic acid gas that the use of three sizes of pigment particles have better results, let us now consider the question, In what proportion are these pigments to be used?

We must frankly admit that thus far the laboratories have not advanced far enough to yield much data that can be used in an exact science, and the experiments to date on this question merely tend to show that the ripe experience of conservative and conscientious paint manufacturers is approximately correct; in other words, that the present high-grade paint formulas combine the particular pigments chosen in about the proper proportions.

Strength
and Elasticity
of Paint Coatings

If we take paint films composed of various pigments and test them with the Perry Film Testing Apparatus, which gives an approximate measurement of the elastic limit, or limit at which a paint skin, composed of linoxyn and the pigment, will break, we get data which show that white lead or similar pigments should be largely used to preserve or, rather, to avoid depletion of the elasticity of the linoxyn; the experiment also shows that zinc oxide or similar material with extremely fine particles should be used in fairly liberal proportion to fill



Film Testing Machine

the pores, but that excessive use of a pigment of this kind will destroy the proper elasticity of the film and produce cracking and peeling.

We also find that asbestine, or similar materials with needle-like structure, used in moderate proportion, add wonderfully to the strength of the paint coating. Thus the result of human experience in compounding high-grade paints is confirmed by the apparatus which measures the porosity of the paint, and again by the apparatus which measures the elasticity and strength of the film.

Practical Field Tests

In order that *scientific* work of this kind and *practical* experience shall proceed hand in hand, and that the public should have definite assurance regarding the *practical* and visible results from all of this work, the paint manufacturers have turned over to their scientific bureau the problem of erecting great test fences to test these paints in a practical way on lumber, and the Scientific Section has requested the official co-operation of the master painters, the architects and various scientific societies.

Master Painters Represented in Test

Through the publication of this section and articles appearing in various trade papers, you are probably aware of these practical paint tests, which have been conducted by the Section during the past year. An outline of these tests has been given in "Paint Modernism," a booklet published by the Educational and Commercial Section of the Association, and sent broadcast period-



View of Atlantic City Test Fence

ically to over 100,000 dealers, users, and other people interested in paint. A complete report of the tests was published by the Scientific Section early last spring, and a copy may be secured by writing to the laboratories of this Section. Because the Master Painters' Association was so prominent in these tests, and because their representatives at Pittsburg and Philadelphia, Messrs. Rapp and Butler, were selected as the official painters of the Pittsburg and Atlantic City fence, respectively, it is felt that every member of the Master Painters' Association should be in touch with this work.

The protection of our homes, of the frame buildings in which we live, and their decoration, is a subject which is of the most interest to the master painter of to-day. This paper is, therefore, confined to the tests whcih we have been making on wooden surfaces.

These tests were started at the suggestion of the manufacturers, at their second annual meeting, in October, 1907. Prof. Ladd, of the North Dakota Agricultural College, the originator of the much talked of paint law of that State, started a test fence with the co-operation of the Paint Manufacturers' Association, to determine, among other things, the very important question, namely, whether two or more pigments in combination in a paint were superior to one single pigment, not, of course, any two or more pigments, good or bad, or any one single pigment, good or bad, but whether two or more good pigments, properly balanced and mixed, were superior to any one of the two or three, where used alone.

Dr. Ladd at that time erected on the grounds of the college a test fence, upon which are painted out several different formulas. These formulas were largely combinations of lead and zinc in varying proportions, and were designed to ascertain the results obtainable from various proportions of these materials. The value of these tests, which have been conducted at the North Dakota Station by Prof. Ladd, under the supervision of the inspector of the Paint Manufacturers' Association, has been recognized.

Two or More
Pigments
versus
Single Pigments

North Dakota
Fence

Climatic
Considerations

The climate of North Dakota, however, being particularly free from moisture and dampness, would naturally allow a paint longer life than in many other parts of the country. Furthermore, the remoteness of North Dakota from the more densely populated centres of this great nation, and the distance which many must travel to reach this fence, has precluded the possibility of frequent inspection by the practical master painters and by other authorities on the subject of paint, and it is to these gentlemen that we are to look for the final verdict of our tests. The results which may be obtained in North Dakota will be interesting, although inspection committees do not seem to have been asked by the authorities to co-operate in last summer's inspection of this fence.

For the reasons cited, it was deemed necessary to have similar tests started in other parts of the United States, where more severe climatic conditions are prevalent.

Atlantic City
Fences

Atlantic City at once suggested itself as being a place in which the destructive elements would afford an accelerated test. The American Society for Testing Materials, a body of high scientific repute, chose a committee, composed largely of governmental scientists, to supervise and inspect the Atlantic City fence, and they have worked in close touch with the Scientific Section and the Philadelphia branch of the Master Painters' Association of Pennsylvania. This latter body chose Mr. George Butler, of Philadelphia, as the official painter of the fence, and his men were present during the entire period. Thus it is clear to see that absolutely unbiased treatment was given every compound applied.

Pittsburg Fences

Pittsburg was selected as a suitable location for another fence because of the variability of its climate, its smoke-laden air and the general conditions which prevail in that city, which would tend to cause rapid destruction of paint. At Pittsburg, the local branch of the Master Painters' Association appointed Mr. A. C. Rapp, the president of that association, as the official painter of the

fence, and his men were present throughout the work, together with the inspectors and chemists of the Scientific Section and the inspectors appointed by the Fence Committee of the Carnegie technical schools, who accepted supervision and inspection of the fence. This latter body is composed of professors of the faculty, who are men of widely acknowledged scientific reputation, and the whole school body has been interested in the tests. If in the future this school is to produce technical men and fit men to better assume the duties of the master painter, the tests which we have started will undoubtedly be of great value to them.

**Importance of
Technical Schools
to the
Master Painter**

Thus, because of the excellent opportunities for rigid control by unprejudiced committees, and because of the opportunity for frequent inspection which these fences afford, and because of the accelerated action which these climates will give, we could have had no better places for such tests.

**Inspection
Committees**

Two other fences are to be erected to test the behavior of paints under normal climatic exposure in the South and Mississippi Valley regions. These two fences, however, have not yet been started, owing to the lack of funds at the disposal of the Scientific Section. The two fences, at Atlantic City and Pittsburg, were erected and painted during the first two months of 1908.

**Future
Fences**

It is recognized that many of the field exposure tests which have been carried out in various parts of the country have been of little value on account of the methods under which the tests were conducted, and of the prejudiced or commercial interests involved. For instance, the adoption of a definite spreading rate in some of these former tests has been criticised as, perhaps, just a little too theoretical, because it requires every paint applied, regardless of its composition, to cover the same number of square feet per gallon. Some paints, deficient in spreading qualities, would thus be forced to cover a larger surface than they were meant to cover, thus producing a thin, easily disintegrated film. This is not what

**Value of
Field Tests**

Methods Followed
in Painting Fences

the master painter would do in practice. The practical painter uses his own judgment regarding the proper spreading of a paint, and it is upon his judgment that we must rely for the conservation of our structures. This practical method was followed on the Atlantic City and Pittsburg fences, the painter using as much paint as the wood required, of course weighing the paint before and after use, so as to determine the amount put on. These weights furnish data from which the spreading rate may be calculated later on.

It has been the endeavor in these tests to cover every practical point possible. Instead of painting out each formula on one panel, each test has been made in duplicate on three kinds of wood, thus allowing each formula six sections of panel, half of which are exposed on one side of the fence, and the other half on the reverse side. The base paints are applied in white, yellow and gray tints, allowing eighteen panels for each type of formula. The paints used for the tests consisted of the particular sixteen formulas which were tried out on the North Dakota fence by Dr. Ladd, and were representative of high-grade lead and zinc combinations.

A series of formulas containing varying percentages of inert pigments, combined with the typical white pigments, were also tried out on the association fences. These paints were designed to show safe limits within which the manufacturer could use these inert pigments in order to benefit and render better for use the paints he is producing. A number of white leads, largely used by master painters of the country, were also tried out upon the fence. These together with a number of formulas of new types, made up the balance of the tests. Various colors, such as reds, blues and greens, were tried out upon the fence, combined with different white base pigments, in order to show which of these white bases could best be used with these colors to prevent them fading, darkening and showing other troublesome results.

The percentage of the reinforcing pigments, such as

silica, blanc fixe, silicates, whiting, etc., which were used in certain of the formulas, will prove a measure of their value when used in small amounts. These pigments have their own marked qualities and defects, but when used with precision, moderation and understanding, their addition to paints lends valuable properties.

Reinforcing
Pigments

At a recent inspection of the fence at Pittsburg one fact is developing very strikingly, with due allowance for changes that may come with time, namely, that the combination of two or more pigments is superior to any one pigment when used alone. Please do not misinterpret this statement; this does not mean that any two pigments, when ground in oil and painted out, will give better service and wear than any of the prime white pigments which are in use to-day alone, but it is becoming apparent that lead or zinc, or any other pigment, no matter how well it shows up, will give still better service when properly combined in wise and moderate percentages with one or more of the other prime white pigments. Again, there can be no doubt that the combination spoken of is bettered still further by the addition of percentages of the reinforcing pigments.

Conclusions Drawn
from
Last Inspections

This statement is made tentatively, as showing the condition to-day, and with the admission that future wear may to some extent change this belief regarding the subject.

The paper was received with applause.

(The paper was accompanied by an interesting demonstration of apparatus to test the strength and porosity of paint films.)

PRESIDENT RAPP:—The paper read by Mr. Perry should be followed by the paper on composite base paints, as they are dove-tailed together, and we will set aside, for the present, any discussion of this paper of Mr. Perry's, until we have heard the paper of Mr. Lane's. The paper is entitled "Composite base paint and its benefits to the master painter," by F. A. Lane of Philadelphia. I take great pleasure in introducing this gentleman to you for the reason that previous to his fall from grace into the ranks of the manufacturers he had been a painter. I introduce to you, Mr. F. A. Lane, of Philadelphia. (Applause.)

“COMPOSITE BASE PAINT AND ITS BENEFITS TO THE MASTER PAINTER”

By F. A. LANE.

MR. PRESIDENT AND GENTLEMEN OF THIS CONVENTION:—Before reading the paper I have prepared, let me thank you for the pleasure you afforded me when your committee notified me I had been selected to come before your Convention. Having been a master painter, naturally I feel more or less at home, and especially so with the Pennsylvania State Association.

Created by
Master Painters

It is needless to point out or dwell on the fact that the material—Composite Base Paint—was created at the suggestion of a number of representative master painters. After several meetings of a committee of master painters and a committee of the Paint Manufacturers' Association, and the wants of the master painters had been explained, Composite Base Paint was made to meet the requirements then set forth.

Analysis on Label

There is no question as to the convenience of such a commodity, coming to you, as it does, in sealed packages of convenient size, plainly labeled as to shade and quality, and showing a true analysis of the chemical contents, and being of a consistency that entirely eliminates the necessity of breaking up, and in a form that permits of its use for any of the varied requirements for inside or outside use—one, two, or three-coat work; flat or gloss, priming or finishing. As the name implies, it is a base, chemically and physically, as near correct as it is possible to make; to which the master painter must apply his skill and knowledge as to the proper thinners and dryers, proper tinting and correct application; all of which must necessarily vary according to the character of the work in hand.

Made Without
Driers

The necessary characteristics of paint are as follows:

1. Stability or chemical inertness, involving the permanency of tints and colors.
2. Strength of film.
3. Elasticity, a quality closely allied to strength. It is the property that allows the paint coating to properly expand and contract under atmospheric influences and with the surface it covers, without breaking or pulling apart.
4. Hiding power or opacity.
5. Spreading or covering properties.
6. Tooth and brushing qualities, proper drag or feel under the brush, essential to all good paints. Tooth is the quality which prevents slicking or brushing out too thin.
7. Non-settling quality.
8. Drying or oxidation, a quality which is largely governed by the master painter himself according to the character of the work in hand, although all pigments must be selected with a view to getting the most perfect drying qualities when used in the presence of pure linseed oil.
9. Penetration. The quality of penetrating or sinking deep into the pores of the wood, thus increasing the tenacity of the paint coating. The addition of volatile thinners to any paint will aid penetration, but it is a well-known fact that some pigments possess greater penetrating qualities than others.

OPACITY or HIDING POWER is most perfectly attained through the use of WHITE LEAD. The Hydrocarbonate, which is made by process of corrosion, is made up of particles of variable size, at least 10 per cent. of which are coarse. Even the finer particles are coarse in comparison with the finer particles of Basic Sulphate White Lead, or the still finer particles of Zinc Oxide. Hydrocarbonate of lead is properly classed as a coarse pigment. Its coarse nature and the variable size of its

particles, also its low oil-absorbing qualities, explain its great Opacity and Density and its good Tooth.

**Hydrocarbonate
of Lead;
Its Qualities and
Defects**

The extent to which hydrocarbonate of lead should be used is determined by the amount that can be introduced for opacity or hiding qualities and for tooth, without introducing its other weak characteristics or qualities. Soft Coal Smoke, Sulphurous gases or barn vapors change the hydrocarbonate to the black sulphide of lead (the cause of discoloration or blackening), the acids of linseed oil unite with it, which disintegrates on exposure to the elements (the cause of chalking), its heavy gravity causes it to settle badly (the cause of non-uniformity on the painted surface).. It has an alkaline tendency, which causes it to attack and destroy certain colors, like blues, greens and reds (the cause of fading or bleaching out of tints and colors).

**Why
Basic Sulphate
White Lead
is Used**

Basic sulphate white lead possesses all the desirable qualities of the hydrocarbonate, with the exception of tooth, a quality which, because of its fineness, it lacks, yet it is entirely free from the chemical activity of hydrocarbonate. Basic sulphate white lead contains about 70 per cent. of metallic lead; but, unlike the hydrocarbonate, which contains about 80 per cent., and which is easily reduced to metal under the blow-pipe, it is practically impossible to reduce the sulphate to metal without a powerful reducing flux, proving that it is a strong pigment not easily affected by heat in any degree. It is exceedingly dense, very white, and more stable and permanent than the hydrocarbonate.

**Value of
Combining
Two Lead Bases**

It is impossible, however, to so combine the hydrocarbonate and basic sulphate white lead as to obtain a coating of maximum durability, or one that is permanently non-absorbent. The chalking tendency of the hydrocarbonate, although somewhat offset by the use of the basic sulphate, would still be apparent to a limited extent, and would be evidence of a porous or moisture-absorbing tendency.

Straight lead coatings lack compactness, therefore the

burden of moisture and weather resistance devolves more on the oxidized or dried film of oil that holds the mass of pigments together and to the surface; hence the earlier destruction or disintegration of the oil which is the binder that keeps the paint coating intact.

This, in part, explains the necessary use of an exceedingly fine metallic pigment that will, in combination with the white lead, form a very close, compact, moisture- and weather-resisting surface that will also afford the largest degree of protection to the oil. Oxide of zinc, the finest, lightest, whitest and most chemically inert of all the metallic pigments, not only meets this requirement perfectly, but it also brings the spreading or brushing qualities up to the maximum, increases the whiteness and insures its permanency, and because of its exceedingly light gravity, introduces an increased percentage of linseed oil or binding principle, and assists materially in keeping the paint in proper suspension. It is a well-known fact that oxide of zinc insures clear and beautiful tints.

Elasticity and strength are the two great requisites of paint that are most commonly ignored or overlooked, and yet they have more to do with the lasting qualities or durability of the paint than all other considerations combined, and it is here that thoughtful consideration is especially necessary.

Practical field tests, as well as scientific investigation, have proven that reinforcing pigments lend certain qualities to paint, but these materials should be used with precision and understanding. You gentlemen realize the importance of the vehicle or liquid portion of a paint coating and demand honest products and proper handling, and yet I one time heard a very able and scientific gentleman, before a convention of master painters, advise them, if they felt white lead needed reinforcing, to buy putty and add to the lead. He, of course, realized that the grade of calcium carbonate used in putty was entirely unsuited for paint purposes, even if calcium car-

**Description of
Zinc Oxide and
Its Necessity
in a Good Paint**

**Reinforcing
Pigments
and their
Proper Usage**

bonate is of value as a reinforcing pigment in some colors, and also that putty usually contains other oils than linseed, and that putty is never ground (only chased), and that carbonate of lead is already quite alkaline, and that the addition of putty would increase the alkalinity and render it still more unstable. Briefly, I shall describe some of the properties and defects of the reinforcing pigments:

Barium Sulphate (Barytes).—Very stable, good tooth, retards chalking; an excellent base for certain colors and lakes, but in paint, settles almost as bad as lead carbonate.

Alumina Silica (China Clay).—An anti-settler, stable and retards chalking, but lacks tooth and opacity; causes paint to work slippery under the brush when used in the slightest excess.

Calcium Carbonate (Paris White, Whiting, etc.).—Corrects free acidity in oils; should only be used in very small proportions, if at all; as it is usually alkaline, it thickens the paint coat beyond the point of efficiency and detracts from its strength if used in excess.

Calcium Sulphate (Terra Alba).—Stable, and has excellent tooth, but lacks almost entirely opacity in oil; very good for interior flat painting when used in reasonable quantities.

Silica or Silex.—Stable, a good filler, transparent in oil; thickens the paint beyond the point of efficiency if used in excess. Owing to its crystalline structure and lack of opacity it makes an excellent filler for finishing natural hard wood.

Silicate of Magnesia (Asbestine).—An asbestos mineral, notable for its fibrous structure and the fact that it holds up heavier pigments in paint; very stable; retards chalking and has good tooth. Asbestine is a great paint-coat strengthener.

After having selected pure linseed oil as our vehicle, and keeping in mind your requirements:

First, Durability;

Second, Appearance;

Third, Condition for repainting after a term of years ;

Fourth, Ease of application ;

We build up the pigment portion. A coating containing basic carbonate white lead would be only fairly white, very opaque, and would possess tooth, but lack spreading qualities, and would chalk badly ; easily repainted, quite elastic, but not extremely strong.

A coating composed of basic sulphate white lead only would be very opaque and white, would resist the action of sulphurous and coal gases to a great degree, and, as it chalks mildly after long exposure and does not peel, it would present a good surface for repainting. As it is neither acid nor alkaline, it has no bad effects upon the oil or other pigments present. But being very fine in structure, it requires blending with some other coarser pigment.

A coating, when the only pigment present was zinc oxide, would be exceedingly white and glossy, resist sulphurous and coal gases, but will surely crack and peel, and does not present a good surface for repainting. Hence the reason for using a good percentage of zinc for color qualities, fineness and ease of application ; a proper percentage of basic carbonate white lead to improve opacity and tooth, and counteract the tendency to peel and add elasticity. A liberal percentage of basic sulphate white lead improves the color, elasticity, working qualities, opacity and power to resist the blackening effects of sulphurous and coal gases of the atmosphere. If it were not for the fact that this combination lacked strength and would have a tendency to brush out too thin, it would be an ideal formula. Therefore, we must add a reinforcing pigment that possesses the characteristics lacking in the opaque white pigments, strengthen the film, retard the chalking or peeling without detracting from any of the useful properties of the opaque pigments.

Reason for Using
More than
One Pigment and
Value of Each

COLORS.—There are eight colors in the line, all of

great importance to the master painter. They are all so compounded that they can be used for both tinting and body colors.

Easy Manipulation
of Color Bases

LEAD COLOR, finely ground opaque color. Every painter knows the difficulties encountered in breaking up lamp black and incorporating it with base properly, so as not to show streaks. By the use of Composite Base Lead Color this difficulty is overcome; and tinting with Composite Base Lead Colors *does not increase the cost* of the paint, as is the case when lamp black is used.

Economy in Use of
Color Bases

LEMON YELLOW.—On account of the spongy nature of all C. P. chrome yellows, they do not make ideal painting pigments if used alone; therefore their value lies only in their tintorial strength; and as their price is about four times that of white lead (sulphate or carbonate), chrome tints increase in cost in proportion to the amount of chrome added. Not so with Composite Base Lemon Yellow, which has been properly reinforced with the logical white pigments and reinforcing material.

CHROME TINTED OCHRE.—A bright, genuine French ochre, toned with pure chrome yellow. As nature has added the necessary reinforcing pigments to the ochre, no additional pigments are necessary. A money saver when used as a tinter of body colors.

BLUE.—Produced from clear-toned Chinese blue, properly reinforced, will give perfect satisfaction, either as a base, body or tinting color. You all realize the importance of a blue to be used in conjunction with a white base, that will retain its brilliancy and color.

Advantage of Using
Reinforced Colors

GREEN, Being a combination of chrome yellow and Prussian or Chinese blue, should never be used in a chemically pure state as a body color, and if used in pure form for tinting, should never be mixed with lead carbonate. I do not believe there is a gentleman here who would attempt to use C. P. Green as a body color, but would insist on a green 20 per cent. to 25 per cent. pure, balance suitable reinforcing material. Let me ask,

why, then, do you not apply the same rule to Prussian blue and chrome yellow, both chemically weak?

BLACK.—A pure ivory black broken down in linseed oil. Used for tinting, and especially for body work, sash, gratings, railings, and, in fact, any place where a jet black coating is required.

TUSCAN RED.—A rich, brilliant sesquioxide of iron pigment, toned with alizarine. Permanent body color, and produces very excellent tints; it has exceptional strength, reinforced by nature.

RED OXIDE.—A permanent red of great strength, smooth texture, high in sesquioxide of iron, reinforced by nature, requires only a thorough grinding and breaking down before it comes to you. It would take too long to describe all of the qualities of this line of material and all of its advantages to you gentlemen. You are all familiar with the delays and annoyances of breaking up colors, the loss of time and material, the straining of colors alone being expensive, not to mention skinning over of opened tinting colors high in price, the great proportion of which is eliminated by the use of Composite Base Paints.

You might say that if you reduce the colors with some white pigment to the same shade the price would equalize. Let us see. Take the yellow, for instance:

Comparative Costs
of Composite Base
Paints vs.
White Lead

1 gallon Composite Base Yellow.....	\$1.75
1 gallon raw linseed oil .....	.50
1/32 gallon oil japan at 80c. ....	.02 1/2

2 1/32 gallons \$2.27 1/2
Cost, \$1.12 per gallon.

Same color and consistency from lead carbonate—

100 lbs. lead	\$6.50
48 lbs. chrome yellow, M., at 20c.....	9.60
6 1/2 gals. linseed oil, at 50c.....	3.25
1/2 gal. oil japan, at 80c.....	40

12 gallons. \$19.75
Cost, \$1.65 per gallon.

A saving for Composite Base Paint of 53c. per gallon, or 47 1-3 per cent.

Let us try the green. Here no lead is used in the calculation—

To 1 gallon Composite Base Green at...	\$1.75
add 1 gallon linseed oil at .....	.50
1/32 gal. oil japan at 80c.....	.02½

2 1/32 gallons.	\$2.27½
-----------------	---------

Cost, \$1.12 per gallon.

19¼ lbs. green, standard quality, at 17c.	\$3.27½
1½ gals. linseed oil at 50c.....	.75
1/16 gal. oil japan at 80c.....	.05

2 9/16 gallons.	\$4.07½
-----------------	---------

Cost, \$1.60 per gallon.

Composite Base saves 48c. per gallon, or 44 per cent., a total of \$2.41 on every 100 pounds of green replaced by Composite Base Green.

Lead color works out like this—

1 gal. Composite Base Lead Color.....	\$1.56¼
1 gal. linseed oil .....	.50
1/32 gal. oil japan .....	.02½

2 1/32 gallons.	\$2.08¾
-----------------	---------

Cost, \$1.02¾ per gallon.

Lead color from lead—

100 lbs. white lead	\$6.50
5 lbs. lamp black at 16c.....	.80
4½ gals. linseed oil at 50c.....	2.25
¾ gal. oil japan at 80c.....	.30

7⅞ gallons.	\$9.85
-------------	--------

Cost, \$1.25 per gallon.

Saving for Composite Base Paint of 23¼c. per gallon, or 23 per cent.

Straight black shows interesting figures—

1 gal. of Composite Base at.....	\$1.56½
1 gal. linseed oil at 50c.....	.50
1/32 gal. oil japan at 80c.....	.02½

2 1/32 gallons. \$2.09

Cost per gallon, \$1.02½.

14 lbs. drop black at 17c.....	\$2.38
1½ gals. linseed oil at 50c.....	.75
1/16 gal. oil japan at 80c.....	.05

2 9/16 gallons. \$3.18

Cost, \$1.26 per gallon.

Saving in favor of Composite of 23½c. per gallon, or 24 per cent.

Now to compare the whites, and I am through. Examination of standard brands of lead carbonate in local markets gives us the following data;

One gallon, 231 cubic inches, of lead carbonate taken from the keg gives an average weight of 35½ pounds, and while the lead is in net weight wood packages at this time 96 to 97 pounds is practically all that can be actually used after deducting the loss by skin and soakage into the wood. Therefore, an average 100-pound keg, actual measurement, yields 2.704 gallons of lead.

To one gallon lead add 1½ gallons linseed oil or to the 2.704 gallons we add 4.05 gallons of oil, gives a yield of 6.75 gallons, or 6¾ gallons.

If raw oil is used, it would be necessary to deduct some oil and add japan, thus:

100 lbs. lead	\$6.50
3¾ gals. linseed oil at 50c.....	1.87½
¼ gal. oil japan at 80c.....	.20

6¾ gallons. \$8.57½

Cost per gallon, \$1.27.

This is too thin for second coat work. Prof. E. F. Ladd, in Bulletin No. 81, pages 673 and 674, calls attention to instructions received by him from a lead com-

Loss by Fattening and
Soakage in
White Lead
Packages

pany to use 4 gallons oil to 100 pounds lead for second coat, and also mentions that this mixture was too thin, and test was repeated with 3 gallons of oil to 100 pounds. Compare this with:

Exterior White—

1 gal. Composite Base	\$1.75
1 gal linseed oil at 50c. ....	.50
1/32 gal. oil japan at 80c. ....	.02½

2 1/32 gals.	\$2.27½
--------------	---------

Cost per gallon \$1.12 as against \$1.27 for lead.

Tint Composite Base, any shade using lead color, black, tuscan oxide or chrome ochre and you reduce the price. Tint it with blue, yellow or green and it remains the same price. Not so with lead, tint it any shade with anything but cheap ochre and venetian red in cheap oil and it costs more than white. Use Composite Base Tinting White for shades instead of Exterior White and you save 10c. per gallon additional.

For interior work you would not think of using straight lead, but suppose you did, how about cost. Let us try flat coating:

1 gallon interior composite at	\$1.83¾
¾ gal. turpentine at 50c. ....	.18¾

1¾ gal.	\$2.02½
---------	---------

One gallon costs \$1.47.

100 lbs. white lead	\$6.50
2 gallons turpentine	1.00

Almost 4¾ gals.	\$7.50
-----------------	--------

One gallon costs \$1.58.

A saving of 11c. per gal. If turpentine goes up the saving increases.

The Composite Base is much superior in color, working and equally good in hiding qualities, and better than a mixture of lead and zinc; in fact, there is no comparison between Interior Composite Base White and other

mixtures owing to the fact this is completely flat, while lead and zinc or either alone dries with an egg shell gloss when thinned all turps, therefore, a true flat job cannot be made. Again, Interior Composite Base White can be used as building up coats for enamel, adding varnish in varying proportions and being assured it will dry hard and firm, and if desired making enamel by the use of varnish only for thinning. In fact, Composite Base Interior White takes the place of lead, zinc, or any combination of the two in oil or japan for interior work.

Gentlemen, I assure you all the tests used for comparison herein were personally made by the writer, surfaces finished and examined before drawing conclusions.

The paper was received with applause.

**Superior Flatting
Properties of
Composite Base
Paint**

**May be Used for All
Kinds of Work**

DISCUSSION

PRESIDENT RAPP:—Gentlemen, you have heard the reading of this very instructive paper by Mr. Lane. What is your pleasure? If there are no objections, the paper will be received and filed in the archives of the association. (There appeared to be no objections.) I think this is one of the really important things of this convention.

MR. THOMPSON (Gustave W., Chemist of the National Lead Company, Brooklyn, N. Y.):—I have been very much interested in the instructive papers read here, especially the paper on composite base pigments, presented to you this morning. The attitude of mind in which I approach this subject, and, I ask your indulgence, is the friendliest that I can imagine. What we want is more information, and, so far as I am concerned personally, and I am sure I represent the sentiments of those with whom I am associated in a business way, if anything cannot stand investigation and the searchlight of knowledge, that material ought to take a back seat. In other words, we are living in an enlightened age. We want all the knowledge we can get.

Taking the question as far as I can, I want to emphasize those points on which I agree with both speakers. If I have to disagree with them it will be with regret and not with pleasure. I want to agree with Mr. Perry, for instance, in the first instance, where he says that a pigment should be made up of particles of different sizes. Mr. Lane in his paper referred to the fact that white lead itself was made up of particles of different sizes. I refer to the "Dutch process" white lead as an example. I make no invidious comparisons as to our brands of white lead. I know something about the "Dutch process" white lead. There have been many attempts to make white lead to take the place of "Dutch process" white lead. Some have been more or less successful. Those that have been successful we wish God-speed. There has been one class of pigments made in imitation of white lead that has not been successful, and those have been the precipitated white leads where the particles are of one size.

Now, it can be found by a very careful examination of white lead by the microscope and by the floating process, that about 50 per cent. of white lead, in my opinion, approaches the fineness of zinc, with about 20 per cent. comparatively coarse—it varies from 20 per cent. down to smaller amounts. I am not prepared to say 20 per cent is a good per-

centage. I am inclined to think, that with the gradual growth of sentiment, a reduction of that 20 per cent. would be advantageous.*

Now, there are in white lead, particles of various sizes. I do not agree—and I think Mr. Perry, when he thinks a moment, will be inclined to agree with me—I do not agree with his statement that necessarily you must have three sizes of particles. From my experience in the matter you may have an infinite variety of particles and get the same advantage. You might have a mixture of two particles, one comparatively small and the other coarse, and get very good results. * (See page 40.)

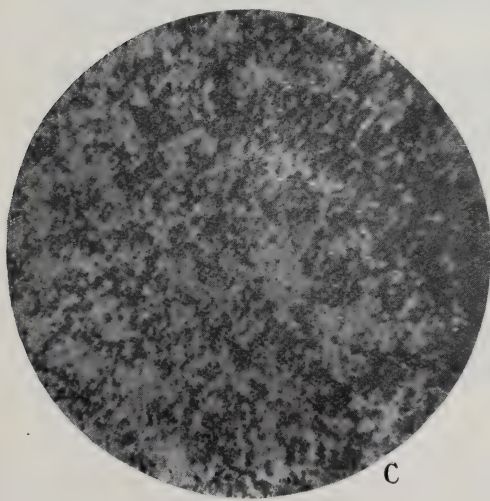
As to the question of porosity of films: As practical men you know the problems presented to you in the painting of wood, and it is in reference to the painting of wood that most of the remarks have been made to-day. You are presented with two conditions—two possibilities. You

*Micro-measurements by Bausch & Lomb:

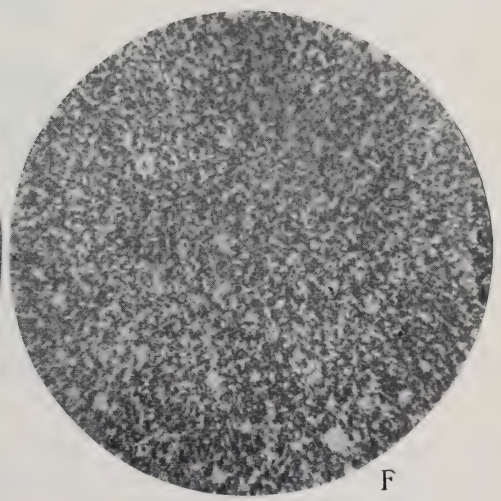
Size of white lead particles.....033000—.000074 in.

Size of zinc oxide particles.....000020—.000020 in.

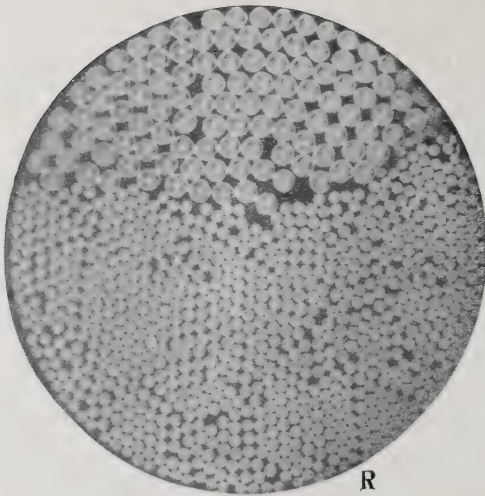
It is thus shown that the smallest observed particles of white lead are over three and a half ($3\frac{1}{2}$) times the size of the practically uniform zinc oxide particles.



C White Lead



F Zinc Oxide



Equal volume (one cubic centimetre) of each size of shot taken. Note that the smaller shot cover more than half as much again as the larger shot and the voids are smaller.

Diagram illustrating two determining sizes of solid particles in concrete.

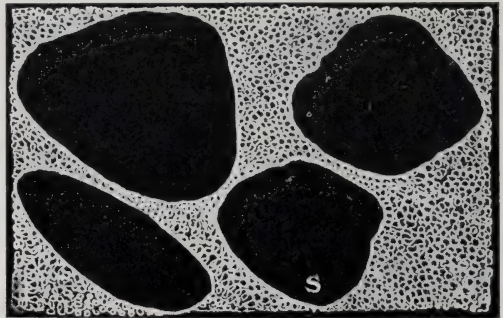
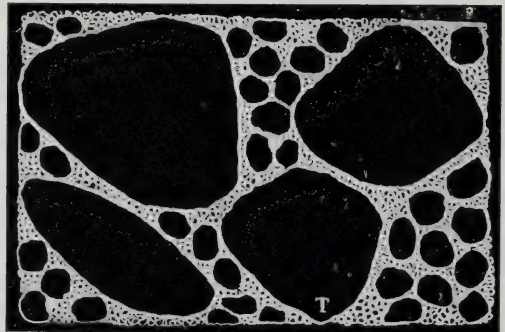


Diagram illustrating three determining sizes of solid particles in concrete.



Note that the medium-sized particles in lower diagram cover areas which in upper diagram have the fine dot particles with voids between them, and therefore we have less void spaces in the lower diagram with the third or medium size particles, and hence less permeability. Therefore a mixture of particles of three sizes gives less porosity than a mixture of particles of only two sizes.

may have an impermeable film. What is the natural result of an impermeable film? Blistering and scaling. You may have an excessively permeable film, and there you have destruction of the pigment of the paint. I do not believe you will get successful results if you make use of an impermeable film. You have had experience with the use of boiled oil, and some of you have said that when you use boiled oil you get blistering. That is a common statement with master painters. My explanation of that fact is that the boiled oil will give a more impermeable film and the moisture in cannot get out. Blistering must result. *

I call your attention to one very important phase of this subject. I have no scheme which is of advantage to the master painter. If you can see any advantage in any proposition put before you in a business way, seize it and make use of it, and get all the profit you can out of it, providing you are giving fair treatment. Bear this in mind, that you, as master painters, carry a certain amount of stock, and, as a business proposition, I ask you whether it is not far better for you, as far as you can practically do it, to keep your stock in the form of staple materials of a more or less permanent value. All paint materials vary in value, but if you have to close out your business, or change your plans, is it best for you to have a material which is made up on composite lines which you may have difficulty in disposing of, or, is it better for you to have your stock of material in such form you can dispose of it? In other words, it has a tangible and concrete value. I do not mean to suggest that composite base paint might not become staple material. I do not know about that. It is not at the present time.

* With a series of films made of linseed oil, both boiled and raw, and mixtures of the two, the Scientific Section found that they exhibited different degrees of exclusion, according to the amount of boiled oil contained in the formula. The film containing the highest percentage of boiled oil exhibited the greatest impermeability, but, like the Composite Base Paint film containing three determinate sizes of particles and the least voids, it showed more than sufficient permeability to provide for the exit of the reasonable and moderate amount of dampness contained in the underlying wood, and the tests clearly prove that excessive moisture in the lumber will find such difficulty in escaping through even the most porous paint film that peeling will result.

If you have in your shop pure white lead, pure zinc oxide, pure materials of different kinds, you have control of the preparation of your paints. I do not believe there is any man here, a master painter, who is not capable of handling that entire thing himself. You have been doing it for years. Do you feel any disadvantage, or feel any necessity for employing a special method of preparing your paints for your use?

Now, there is another phase of the subject. It was not brought out to-day by either of your speakers, although it was slightly intimated, as near as I can make out. The composite base paints suggested are not of any definite formula or composition. The idea, as I have understood it—I will be very glad to be corrected if I do not understand it aright—the Paint Manufacturers' Association believe that this is a good thing. I have no desire to attribute any improper purposes or thoughts on their part. They have a promoting section. They go to all the manufacturers of the country and say: "Here is something which we offer to you as a line of work. We do not specify formulas. We believe your formula is the best, Mr. Manufacturer A, follow your formula; B follows his formula; C follows his formula." *

In other words, in the present state of the art, there is nothing standard as to formula. If it is feasible and a mixture of various pigments is the best thing, something will be standardized. But it is not done to-day. There is nothing standard in the matter of the composition of composite base paints, as I understand it.

•Let me say a little further along that same line, composite base paint comes to you under a name, sold under the name of some single staple article. I do not mean to insinuate that composite base paints come in the same class as "Climax" white lead, which Mr. Rapp referred to, but, yet, they will have to bear the name which attaches to the "Climax" white

* The object of allowing reasonable latitude to the manufacturers of this product was to avoid the difficulties experienced with rigid standardization in the past.

So far as Composite Base Paint is concerned, the formula is rigidly scanned, and its practical working carefully tested before the license is issued to the manufacturer, and the formula, upon the label, gives all the information regarding it, that the most exigent Master Painter demands.

lead family; and they will have a great deal of difficulty in getting away from that.*

* The following sets of formulas show the composition of several lines of licensed Composite Base Paints now on the market, the names of the several manufacturers being omitted for obvious reasons. The formula of Outside White, as being of most interest to the painter, has been chosen here, and these formulas are illustrations of the high-grade paint materials used throughout the line:

	1	2	3	4
Pigment.	72.69	76.00	70.67	73.53
Vehicle.	27.31	24.00	29.33	26.47
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>
	<u><u>100.00</u></u>	<u><u>100.00</u></u>	<u><u>100.00</u></u>	<u><u>100.00</u></u>
*Pigment Base	89.55	85.00	81.00	90.00
Barium Sulphate			4.00	
Precipitated Barium Sulphate			8.00	
Silicate of Magnesia (Asbestine)		15.00	2.00	5.00
Calcium Carbonate			5.00	
Silica	10.45			5.00
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>
	<u><u>100.00</u></u>	<u><u>100.00</u></u>	<u><u>100.00</u></u>	<u><u>100.00</u></u>
Linseed Oil	100.00	100.00	96.38	75.70
Turpentine				12.15
Benzine			3.62	
Petroleum Spirits				12.15
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>
	<u><u>100.00</u></u>	<u><u>100.00</u></u>	<u><u>100.00</u></u>	<u><u>100.00</u></u>
*Pigment Base Formula:				
Basic Carbonate White				
Lead	66.00	29.40	66.60	66.60
Basic Sulphate White				
Lead		17.60		16.70
Zinc Oxide	34.00	53.00	33.40	16.70
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>

It is a curious thing, and I want to say this—a repetition of my friendly feeling—it is a curious thing that composite base paints made their appearance at a time when legislation was taking place to prevent the placing of mixtures under the brand of white lead. There may, or may not be, a significance in that. I do not mean to insinuate or suggest that there is any relation or parentage there at all, and, yet, I am inclined to think many consumers will look upon composite base paints in that manner.

As to comparisons of cost, made by Mr. Lane, you may remember he is comparing composite base paints with white lead, a staple material. We wish we could get away from it, but we cannot, that white lead is an expensive paint. The cost is high. You have got to pay for it if you want it. The comparison was between composite base paints and white leads. I am sorry Mr. Lane did not give us a comparison between the cost of paint made by using composite base paint and the cost of the same paint made by using the raw materials from which composite base paints are made, purchased by the master painter and mixed as he thinks best. I believe every paint manufacturer should get his profit, but you know that the margin of profit in ready-mixed paint is far greater than in any other class of paint materials. Composite base paint I do not put in the same class as ready-mixed paint, but, if you attempt to figure on the cost of ready-mixed paint and compare it with the price you will find something like this, as I found in a certain paint in the east: The materials cost 44 cents a gallon, and it was selling at \$1.25 a gallon. I am not going to say that that would be the relation between the price of composite base paints and the cost of materials, and, yet, it will come somewhere around there and approaching that great difference. If you figure out the cost of paint made, using composite base paints, with the cost of using the raw materials which enter into it, you will find far greater disparity than explained between composite base paint and white lead. *

* Supplementing the discussion between Dr. Thompson and Mr. Lane, as to the comparative cost of the contrasted paint products, some detail of the cost of the average of Composite Base Paint Exterior White is here given:

Average percentage of zinc oxide and white lead 86.40 per cent. Proportion of zinc to lead is as one (1) in three (3). Average weight per gallon, 18 pounds.

* I want to take this opportunity of correcting a reference made by Mr. Lane to some remarks made by me at the New Orleans Convention. I do not think Mr. Lane intentionally misquoted me. He referred to some one there as having said that if the painter wanted to put in a reinforcing pigment, he should use whiting. I gave that as an illustration of how the painter could buy the raw material if the painter wants to buy raw material, such as whiting, to put in his paint. If whiting isn't fine enough, he can get it ground in oil so as to use it. I do not advocate the use of putty in white lead, and I am sure Mr. Lane would not want me to be understood by you as advocating its use. I said if you want to put in a pigment like carbonate of lime, buy it in its pure state, its staple form, and use it, then you can get the greatest profit and best advantage.

As to inside flat work: You know sometimes statements are made that things cannot be done, and the only answer you can make is, they are done; and, so far as inside flat work is concerned, there is more white lead probably used, especially in the east, than any other product. With straight white lead, for inside flat work, you don't get an egg-shell gloss, but you get a flat finish. There is no need telling you it cannot be done, because it can be done.

I thank you for this opportunity of being with you, probably the last time for a year at least that I shall have a chance to speak to you. I have been very much gratified and benefited by the opportunity of being with the master painters of this state.

MR. PERRY:—I want to say I appreciate the remarks of Mr. Thompson and the friendly spirit in which they are made. I find myself in the very happy position of agreeing with practically everything he has said regarding my little paper and my experiments.

The only criticism—and I won't even call it criticism—I can make

* While not important, the report of the New Orleans convention shows the exact language of Dr. Thompson's remarks, as follows:

"You can compound your own mixtures whatever they may be, just as well as the manufacturers. I say that deliberately. If you want barium sulphate in your paint, you can buy it ground in oil and add it as you need it. If you want to add whiting to your paint, you can take putty and add it," etc.

is to draw attention to the fact that I said just what Dr. Thompson now says about the permeability or porosity of paint. I don't want anybody to believe I said a coat of paint ought to be impermeable like a rubber coat. Dr. Thompson is quite right in saying that if it were an absolute coat like rubber, it would not let the moisture through. I said, you remember, that the highest grade product we have been able to make still lets some carbonic acid gas through it. You cannot get, in my judgment, and I do not believe we ever will get, so long as we use linseed oil as a vehicle, a coat of paint that will not let *some* of the gases through. And, therefore, there is no danger of our going too far in that direction if we use our technical knowledge properly.

The other point is the question of the fineness of white lead, versus zinc oxide. Dr. Thompson may be right. He is a great chemist, a great authority, but so far our laboratories have not found any other material made that is available for paint, that is, as fine in its particles as zinc oxide. Zinc oxide is so extremely fine that when it is passing from the furnaces, in which it is made, over to the building in which it is collected in bags, it passes as a fume and acts as a gas with gas tension until it settles. Mr. Heckel knows more about the detail of that than I do.

One other thing I want to say. I have condemned over 50 per cent. of the composite base paint formulas which have been presented to the Scientific Section for approval before they go on the market. Over 50 per cent. have been condemned. No composite base paint is allowed to go on the market under copyright, until it passes through the Scientific Section. We do attempt to keep it to a high standard.

I particularly said I was not going into commercial matters. I am here as a laboratory man to give you what technical knowledge might interest you.

MR. DEWAR:—We have learned with a great deal of satisfaction the learned discourse of Mr. Perry upon the subjects of oil and combination of pigments; likewise, from Mr. Lane. We have, also, listened to the thoroughly practical talk by Dr. Thompson.

Admitting everything that has been said, what does this all mean? It means that you and I, as master painters, are the interested parties in this matter. These gentlemen did not come from the laboratories and bring their apparatus with them just to have a simple, informal talk. It means something. The talk of Dr. Thompson means something. And it is directed to you and I, gentlemen.

Now, I quite agree with Dr. Thompson when he says that we are capable, as master painters, and I am sure that every master painter in this room would feel it a personal insult were his ability questioned. To manipulate the colors which he seeks, or the pigments which he has to combine, has not been questioned to produce results.

This great question does not affect us so much to-day as it will to-morrow. I want to reiterate what I said a moment ago, that every master painter within the hearing of my voice would take it as a personal insult were he accused of not thoroughly and practically understanding the combination of pigments to produce results, to meet certain conditions as he meets them, from day to day, in the performance of his vocation as a master painter.

How many men have you in your employ, gentlemen, that you can send out to a job and say: "Produce a paint that will meet the conditions as you find them?" When I say 10 per cent., is that too much? That is pretty near what it would be during a busy season when our shops are crowded with work and we are hiring every man who presents himself and claims to be a practical painter. "I am going to send lead, ochre, venetian red, oxide of zinc, oil, turpentine and dryer, to the building, and here is the color card with the color which I want you to reproduce in the paint and apply it to that building." He goes there. About 95 per cent. won't get the shade. Over 20 per cent. of the men to-day do not understand the conditions the work will show when he arrives there and what quantity of lead, what quantity of zinc, what quantity of other materials, oil and turpentine will meet those conditions. To-day we have not the all-round mechanic we had twenty years ago, or ten years ago, either, and they are getting less and less. And you and I, gentlemen, are to blame. We have not the apprentices in our employ to whom we are teaching the nature of our business, and, therefore, we will be confronted on the to-morrow with the necessity of a simplification of our business owing to the lack of knowledge in our men.

What we want to-day is information as to the better course to pursue, and it is up to the manufacturers, let it be of lead, let it be of composite base paint, to present to us something that will meet the requirements.

We do not know and we cannot know anything at all about the combinations until we personally have tried them out. We cannot stand here and condemn them, for the reason we have never used them. We know what we can produce with lead as a pigment, and we know that,

with a percentage of oxide of zinc, we can produce better results than with the straight lead and oil. Everyone of you will agree with me when I say that we can take 100 pounds of lead, break it up, paint a building pure white with carbonate of lead, using the proper proportions of turpentine, oil and dryer, and we will take a hundred pounds of lead, tint it a straw or buff color, with a good ochre, temper it with oil and turpentine to meet conditions, paint the building under the same conditions and that buff color will outlast the straight lead color in wearing properties by 24 per cent.

Mr. Perry has said that he has condemned 50 per cent. of all the analyses put up to him by the different manufacturers of composite base paints. But, how many manufacturers of paint that won't put their formulas up to be O. K'd. by the Scientific Section, but will go out and lay claim to everything that is good and proper for their composite base paint. Therefore, the necessity of you manufacturers endorsing and working for legislation that will show up the manufacturer within your own lines, who either doesn't know when he has got a good composite base paint, or the manufacturer who doesn't care whether he has it or not, but has something he can make a lot of money out of.

I think the necessity for honest labeling of paints has been demonstrated this morning by Mr. Perry, Mr. Lane and Dr. Thompson. You were told yesterday about the package labeled "white lead" and put there for the purpose of deceiving you and I and the consuming public, put on there that we might be led to believe it was white lead and would buy and use it for that purpose. And there are others all over the country. Therefore, the necessity of knowing just exactly what we are getting. The manufacturers of composite base paints claim for each and every constituent part or different pigment, it will produce certain results, and we will never know it without making a practical demonstration to find out whether the claims of the manufacturers are, or are not, what they represent them to be.

Gentlemen, this is an education, and this lecture by the gentleman this morning will be heralded all over this country. We are alive to the question. We are in the dawn of a new era of knowledge in the manipulation of and knowing what should be a good, practical paint.

MR. FOWLER:—I wonder if this is going to fill the bill for you and I. Is this going to get "fatty"? As soon as you put paint together and

keep it together it gets "fatty," and you know as well as I do you cannot finish a job with that. You know what lead and oil will do after mixing.

Another question. Do you know anything about mildew? Will this stop mildew? Some will mildew more than others. If anybody can give me anything on that I will be glad to receive it. We have that trouble at the seashore. We have work done in the spring and fall, and after done three months it looks bad.

MR. HECKEL:—The formula of composite base paint is on the package in every case, and the license to use the label is issued by me. The formula must appear on the label and must be passed upon by the Scientific Section before any manufacturer is allowed to use the copyrighted label. *

SECRETARY LANE:—I have sufficient confidence in the test fence proposition to believe it will be the very manner of answering the question propounded by Mr. Fowler as to mildew and all that sort of thing, because being tried out in several parts of the country. That will come later.

I rise to my feet to ask, if I may, without any desire to precipitate a discussion, to ask Dr. Thompson the reply he has to make to certain statements made by the advocates of composite base paint. There was a time in the history of the manufacture of white lead when it became absolutely pure. Previous to that time it had been adulterated more or less by what are now termed these reinforcing pigments, and, it is asserted, that since that time white lead has been made absolutely pure, began the difficulties which we encounter now so frequently of the paint chalking shortly after being applied.

DR. THOMPSON:—I am glad to answer the question. It is a fact that the manufacturers of white lead years ago did put out two or three brands of white lead. So far as my knowledge goes, no manufacturer of white lead manufactured mixtures exclusively, but put out pure white lead, and put out another grade with some barytes in it and, perhaps, other things. The time came when the manufacturers of white lead recognized the error of their ways—probably twenty or twenty-five years ago, thirty

* To show the impossibility of an improper use of the Composite Base Paint label, a copy of the label is here reproduced, omitting the name of the manufacturer:

Made Exclusively for Painters' Use

COMPOSITE BASE PAINT

EXTERIOR WHITE



FIVE GALLONS, U. S. MEASURE

ANALYSIS

	Weight	Pigment	Vehicle	Total
Pigment
*Color
Vehicle

*Color is

Composed of: {

100.00% 100.00% 100.00% 100.00%

FORMULA APPROVED BY
SCIENTIFIC SECTION
PAINT MANUFACTURERS'
ASSOCIATION

Label approved and adopted by joint committee of Master Painters and Paint Manufacturers, Detroit, July, 19, 1907. Formula must appear on label.

NAME OF MANUFACTURER

CITY

STATE

U S A

years ago—recognized the error of their ways, and from that time on, white lead has been made strictly pure.

As to the question of deterioration of white lead more rapidly than formerly, that is a question of fact, and the master painter is better able to judge than I am. I haven't the information to affirm or disprove that statement, but when we recognize the fact that master painters in those days largely used white lead, and it is probable the largest portion of the sales of the manufacturers and corrodors was pure white lead, it can hardly be said if, at the present time, white lead does not wear as well as twenty-five years ago it is due to the fact that they don't put barytes in it. *

PRESIDENT RAPP:—Regarding this fence in Pittsburg, a committee of the local was asked to take charge of this test in connection with the Carnegie Technical School. Mr. Dewar, Mr. Cluley and myself were appointed the committee. The application was made under the direction of one of the representatives of the Paint Manufacturers' Association of the United States. Those panels are about 18 inches by 3 feet, three different kinds of wood, and in the neighborhood of a hundred formulas

* Dr. Thompson's answer to Secretary Lane in regard to the relative proportions of pure lead and combination leads sold by corrodors under the old conditions hardly represented the true state of affairs at that time. Naturally no outsider can obtain exact statistics; but the writer has certain statistics regarding at least one important corroding company of that day.

In a letter to him under date of April 23, 1898, a gentleman who was, if memory serves, superintendent of the plant in question during the period covered by his report, says:

"I send you copies of the formulae revised by the _____
LEAD & OIL CO., OCTOBER, 1867:

.....
.....
.....

"We sold some of all the graded brands, and I think fully three-fourths of all our sales from 1864 to 1870 were graded leads."

All this may or may not have a bearing upon Secretary Lane's suggestion, but it is at least of interest.

proposed by the manufacturers. This committee is in the position to-day of the man who wants to be shown. It is a very interesting test, but we cannot say a word about that yet—as to which would be the best formula. We have had the summer's heat of last summer on these panels, and now we have the extremes of winter, and by next May I think we will know something about it. But to-day we do not know anything about composite base paint. We are in the position of the man from Missouri. I am highly interested in the thing because I think demonstration is the fairest way of judging paint materials. (Mr. Rapp explained that the formulas of the different applications are carefully guarded.) I know nothing of the paint on any one of these panels except this, that there are quite a lot that are in very bad condition. (Laughter.) And some are in good condition.*

If a composite base paint with 10 per cent. of barytes is a good thing we want to know it, or 90 per cent. barytes. We want to know if reinforcing materials are the proper thing. If they are we want to know the safe line to go to, and where it is reinforced to adulteration. That is what we are after.

MR. LANE, F. A.:—There are one or two little things I want to mention. I am not a scientific, so-called “wise guy,” but just a plain manufacturer, and the results I have given you are not really based on the manufacturers' point of view, but are good results from the side of the master painter. I want to say that if white lead did not chalk it would be the ideal pigment, and have practically said so in my paper, but it does chalk, and chinks very badly.

I do not think it is the doctor's intention to ask this body of master painters to go back to their apprenticeship days. I remember the first day I reported to my boss as an apprentice and my thoughts when evening came. I don't think he wants us to go back to that stage. He doesn't want us to go back to grinding our own colors. He doesn't expect us to buy white lead dry, and buy the oil from somebody else. That is not the intention. And by that same token he should not object to adopting something new, if that something new is good.

* In connection with Mr. Rapp's remarks about the test fences it should be stated, in justice to all concerned, that several of the formulas contain great excesses of inert materials, the object being to demonstrate, if possible, the dangers of abuse along these lines.

Following the words of your President, I don't believe it is possible to satisfy men from Missouri, if they won't let us show them. If you won't take hold of it, and try it, it is impossible to do it.

Dr. Thompson has said that it is possible to make an interior flat job with lead in oil. The doctor only displays his ignorance as a journeyman painter. With due respect to the doctor, a scientific man, and, I hope, a good friend of mine, I cannot do it, and do you know I have talked with some of the members, lots of the master painters, and can find nobody that can do it, although the doctor says it is being done. Possibly he will tell me who is doing it. My best friends, and those who are not my best friends—because they don't know me—cannot do it. I want to say to you, composite base paint, interior white, the materials I am speaking about, is positively flat.

I regret if I have misquoted the doctor in reference to the New Orleans meeting, but I was present, and if my ears served me right, the doctor said barytes, or putty, or whiting, or calcium carbonate. If I am wrong I apologize to the doctor. I cannot afford to quarrel with him.

The convention here adjourned until 2.30 P. M.

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- Handbook on Petroleum —*Thomson Redwood*
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- Chemical Technology and Analysis of Oils Fast and Waxes
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- A Treatise on Color Manufacture —Zerr & Rübenkamp
 Outlines of Qualitative Chemical Analysis —Gooch & Browning
 Manufacture of Paint J. Cruikshank Smith
 A Practical Handbook for Paint Manufacturers
 The Chemistry of Pigments —E. J. Parry
 House Decorating and Painting —W. Norman Brown
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 —Treadwell Hall
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 Text-book of Chemical Arithmetic —Wells
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 Techno-Chemical Analysis Lunge-Cohn
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 Microscopy of Technical Products Hanausck Winton
 Manipulation of the Microscope —Edward Bausch
 Micro-Chemical Analysis —Behrens
 Pamphlets
 The Corrosion of Iron —A. S. Cushman
 Corrosion of Fence Wire —A. S. Cushman
 Some Technical Methods of Testing
 Miscellaneous Supplies —P. H. Walker
 The Analysis of Turpentine by Fractional
 Distillation with Steam —Wm. C. Geer

Publications of the Scientific Section
Bureau of Promotion and Development
Paint Manufacturers' Association
of the United States

Tables of White Pigments and Vehicle—Standard Nomenclature.

Standard Can Sizes Recommended to Paint Manufacturers.

First Report on the Test Fences Erected by the Scientific Section.

Methods for the Analysis of the Vehicle Constituents of Paint.

Tests Upon the Corrosion of Iron to be Conducted by the Scientific Section.

First Annual Report of the Scientific Section.

Preliminary Report on Steel Test Fences

Report of Committee "E" on Preservative Coatings for Iron and Steel.

Recent Technical Developments in Paint Manufacture.

Protective Coatings for Conservation of Structural Material. (In press.)

The Corrosion of Iron. *By Alfred Sang.*

The Function of Oxygen in the Corrosion of Iron. *By William H. Walker.* (In press.)

Report of Committee "E" on Preservative Coatings for Iron and Steel.

PRESENTED AT THE ANNUAL MEETING OF
THE AMERICAN SOCIETY FOR TESTING MATERIALS,
ATLANTIC CITY, N. J., JUNE 26, 1908.

HAVRE DE GRACE BRIDGE TEST

INCLUDING

ANALYSIS OF PAINTS AND ANALYTICAL METHODS

BY

P. H. WALKER AND P. C. McILHINEY.

Authorized Reprint from the Copyrighted
PROCEEDINGS OF THE AMERICAN SOCIETY FOR TESTING MATERIALS,
PHILADELPHIA, PENNA.
Volume VIII, 1908.

COMPLIMENTS OF THE
SCIENTIFIC SECTION
PAINT MANUFACTURERS ASSOCIATION
PHILADELPHIA, PA.

Consulting Board:
CHARLES B. DUDLEY, Ph.D.

Chemist
Pennsylvania Railroad
Alltoona, Pa.

ALLERTON S. GUSHMAN, Ph.D.
Assistant Director
Office of Public Roads
Agricultural Dept.
Washington

S. S. VOORHEES
Engineer of Tests
Office of Supervising Architect
Treasury Dept.
Washington

BUREAU of PROMOTION and DEVELOPMENT Paint Manufacturers' Association of United States

SCIENTIFIC SECTION-ROBERT S. PERRY, Director

3500 Grays Ferry Road, Philadelphia

January 12, 1909.

TO THE MEMBER OF THE PAINT MANUFACTURERS' ASSOCIATION:

Enclosed you will find a copy of the Report of Committee E. of the American Society for Testing Materials, on the Havre-de-Grace Bridge Test, which, as you are probably aware, was started two years ago in order to determine the value of many Protective Paints upon the market.

These tests were made on a series of steel plates set in a row along the girders of the new Pennsylvania Railroad bridge crossing the Susquehanna River at Havre-de-Grace, Maryland, and also on sections of the bridge proper. The Report of the Committee shows the condition of the paints in Jan., and, though some have already shown marked inferiority, it is evident that longer service conditions are necessary before any definite conclusions can be reached as to the value of each paint.

The analyses of the paints, by Walker and McIlhenny, will prove of great interest to the manufacturer of protective paints, as affording a comparison with his own formulas.

For the benefit of those readers who are not familiar with the chemical symbols, such as are used in the analysis tables in the back of the report, the following description may prove of value:

CaO is the symbol for calcium oxide, commonly known as lime, and may be interpreted as being present either in the form of the sulphate (gypsum) or carbonate (whiting).

MgO is the symbol for magnesium oxide and was probably present in the paint as the silicate of magnesium (asbestos or talcose).

ZnO is the chemical symbol for zinc oxide.

Pb3O4 is the symbol for red lead.

ZnS is the symbol for zinc sulphide, and, when contained in any considerable quantity in paint, lithopone is to be looked for.

PbO is the symbol for oxide of lead, and, as present either as litharge or as the basic part of sublimed white lead.

Al_2O_3 is the symbol for aluminum oxide or alumina and is present in considerable quantity to indicate the presence of aluminum silicate or china clay. If present in only minute quantities, it is generally reported together with the Fe_2O_3 . When reported together as is the case in the following analysis table, the reader will know that the pigment is largely iron oxide and the amount of alumina is very small.

Fe_2O_3 is iron oxide and may represent either Indian red, Princess Metallic Brown or the other oxides of iron which are so largely used.

The work on Havre-de-Grace Bridge on Proprietary Compounds, together with the work on the new steel test fences at Atlantic City, on the worth of the various pigments (see Preliminary Report on Steel Test Fences), will give the manufacturers extremely valuable information for their future guidance in the compounding of protective coatings.

R. S. PERRY, Director,

Scientific Section.

My dear Mr. [illegible]

I have just received your letter of the 11th inst.

and am glad to hear that you are well.

I am writing you a few lines to let you know

that I have received your letter of the 11th inst.

and am glad to hear that you are well.

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that I have received your letter of the 11th inst.

REPORT OF COMMITTEE E ON PRESERVATIVE COATINGS FOR IRON AND STEEL.

The work of the Committee has followed the lines presented in the last annual report in continuation of the service test on the Pennsylvania Railroad bridge over the Susquehanna River at Havre de Grace.

The analysis of the fifty-seven paints applied to the nineteen sections of the bridge has been completed. The results were obtained by two independent analysts, Mr. P. H. Walker and Mr. P. C. McIlhiney, two members of the Committee who were directly in charge of the work. Mr. Walker's report is embodied in Appendix I, and the results obtained by Mr. McIlhiney are presented in Appendix II to this report (Plates IV, V and VI). The analyses were conducted in a very thorough and complete manner and give a clear indication of the composition of the pigment. The results obtained on the volatile part of the vehicle also give satisfactory indications of the composition. The results obtained from the analysis of the fixed oils, however, fail to give as much information as is desired relative to the quality, and in some instances even the nature of the oil. The constants which are the basis of conclusions are so modified by the oxides in the japan and in some cases by combination with the pigment as to be nearly valueless. These points will be fully detailed in report on analysis of the paints.

The result of the last official inspection made in May, 1908, is given in the following report of the Chairman of the Sub-Committee on Inspection:

PHILADELPHIA, PA., June 1, 1908.

MR. S. S. VOORHEES,

Chairman, Committee E, American Society for Testing Materials,
Washington, D. C.

Dear Sir:—

Comparison of independent notes of inspection of Havre de Grace Bridge on May 4, shows that the large majority of the paints are, to date, affording fair protection. The films are generally hard, elastic and adhesive, but noticeably lacking in lustre or gloss, with the following marked exceptions:

Paint 1. The gloss is markedly high; other characteristics as generally noted.

Paint 2. The film is badly fissured and cracked when observed under a glass, indicating early disintegration.

Paint 10. Higher gloss than generally noted, though very slight in comparison with No. 1. The film is brittle and shows tendency to alligator.

Paint 14. The film is lustreless but hard and brittle; badly cracked, showing lower coat. This feature is very noticeable on the lower chord bars of the bridge and particularly on the north side.

Paint 15. The film is failing seriously in nearly all panels though less on No. 600 than on the others. The bridge proper shows unmistakable evidences of rust with marked failure of the coating.

The general remarks relative to panels are applicable to the bridge proper. When anything is noticeably different between panels and bridge, it is noted.

(Signed) W. A. AIKEN,

Chairman, Sub-Committee on Inspection.

As was anticipated, no marked differences are noted in the majority of cases. As was clearly indicated at the inspection a year ago, the only example of an asphaltum coating thinned with a petroleum volatile solvent has failed to a marked degree after eighteen months exposure. A carbon paint containing rosin in the oil has developed minute fissure cracks all over the surface. While it is by no means conclusive that this failure is due to the rosin, still it is well worthy of note, and will be the subject of further investigation.

An example of difference in expansion of a red lead under-coat and a carbon final-coat is shown in Panel 14. The carbon coat has cracked badly on the bridge proper in cobweb-like cracks showing the red of the under-coat. The same final-coat applied also as an under-coat has not failed in this manner.

It is also interesting to note that one of the pure red lead pigments in straight raw linseed oil shows unmistakable evidence of alligatoring.

High gloss and tenacious film is shown by Panel 1. In this case the pigment consists of oxide of iron, red lead, and a carbon black mixed with a varnish containing some gum and thinned with turpentine.

The other panels or sections, as stated in the report of the Sub-Committee, show in most cases a marked loss of gloss with

minor differences in hardness, tenacity, toughness, and elasticity of film. These differences are, however, too slight to warrant expressing an opinion at this time.

There is evidence of rusting, to a slight degree, on all sections of the bridge, due to mechanical injury. These spots have been accurately noted and will be carefully watched at subsequent inspection. In general, however, the paints are affording good protection and it will require longer exposure to differentiate in the majority of cases. Still, each year will eliminate one or more of the paints as showing marked signs of failure.

The report of the Director of Tests, who was personally in charge of the work, is attached as Appendix III to this report. It shows the method followed in cleaning the surface and applying the paint, and the method used to determine the amount of paint applied per unit of surface, together with the Director's personal observations relative to the test. This report will be of much value in conjunction with the detail sheets giving data on surface and application of paint to each section. It will also be used in connection with reports of inspection.

It is becoming more and more evident that some form of laboratory accelerated tests are required to give indications of the value of a preservative coating. Individual members of the Committee have given this subject most serious consideration.

It is felt that the problem should be attacked by investigating the causes of destruction, the function of both the pigment and the vehicle, and the changes occurring during oxidation. It will be of much value to make a micro-photograph of the film in the condition resulting from normal application to the surface. Also micro-photographs of thin smears of the pigment will show clearly the relative size of the pigment particles. It will also be necessary to measure, and if possible express in relative or even actual terms, the hardness, tensile strength, elasticity, permanent set, adhesion, permeability, etc., of the film both *in situ* and detached from the surface.

One great difficulty has been the preparation of the film suitable for comparison. So far it has been impossible to prepare films from different paints containing different percentages of pigment and vehicle, so that they will be of comparable thickness. As the properties mentioned are largely a function of the vehicle,

the results will not be comparable with varying amounts of pigment.

It is felt that valuable data can be obtained by comparison of the results after different conditions of exposure. Investigations of this character, to be of value, must be conducted in the most painstaking and time-consuming manner, and it has been impossible for any member of the Committee to devote to this investigation the necessary time. The importance of the subject is more than sufficient, however, to warrant continued investigation, and it is hoped that by the next annual meeting, your Committee can report some practical method of making laboratory accelerated tests.

The following letter was received from the Secretary of the Paint Manufacturers' Association:

PHILADELPHIA, October 26, 1907.

MR. S. S. VOORHEES,

Chairman, Committee E, American Society for Testing Materials,
Washington, D. C.

Dear Sir:—

Doubtless you are familiar with the paint tests undertaken at the request of the Bureau of Promotion and Development of the Paint Manufacturers' Association of the United States, by Professor E. F. Ladd, and the North Dakota Agricultural College, at Fargo.

At a meeting of this Bureau held in Chicago on October 24, 1907, it was decided to duplicate the North Dakota tests at various points in the country with a view to determining the modifying effects of different climates, etc. One station selected for these extra tests was Atlantic City, N. J., and it is proposed that Committee E shall accept the supervision of these tests in the same manner as the North Dakota tests were accepted by the Agricultural College of that state.

It is desired that the Atlantic City test shall begin as soon as possible, and certainly this fall. If Committee E will accept the proposition to supervise the tests, and to assume jurisdiction over them during their continuance, the Bureau of Promotion and Development will pay all expenses connected therewith, including the supplying of the paints, analyses, erection of the fence, application, etc. As the time is very short, prompt action is necessary. Therefore, will you kindly take the matter up at once with the various members of the Committee by mail and ascertain whether they are willing to accept the responsibility suggested. My vote, of course, is in the affirmative and I have already informed the Bureau that I think the Committee will be quite willing to do what is asked of them. I have also communicated with Mr. Robert Job, who, I believe, thinks very favorably of the proposition.

It is proposed to either rent a piece of ground at a proper situation for the fence, or to ask the Pennsylvania Railroad Company, who doubtless own a great deal of land in the vicinity of Atlantic City, to allow us to erect a fence somewhere on their property. I am writing Dr. Dudley personally regarding the matter, suggesting that he ascertain for me whether such a piece of ground can be secured.

(Signed) G. B. HECKEL,
Secretary.

This offer was very carefully considered by the members of the Committee. It was recognized that such a test was much needed. It was felt, however, that these tests should be planned, developed and controlled entirely by Committee E, if the Society was to be responsible for the result. This was not possible, as the Paint Manufacturers' Association had prepared the paint on the formulas determined by them and had them ground in the special oils and jans desired. It was finally decided by the majority of the Committee to accept the supervision of the application of the paints, and a sub-committee was appointed with the understanding that its chief duties were to see that the paints prepared by the Paint Manufacturers' Association were fairly applied and to give reports in its several subsequent inspections only as to the relative appearance of the various panels. The first report of this Sub-Committee is as follows:

MR. S. S. VOORHEES,

Chairman, Committee E, American Society for Testing Materials,
Washington, D. C.

Dear Sir:—

By your direction a sub-committee composed of the following: Messrs. Aiken, Heckel, Sabin, P. H. Walker, and Robert Job (Chairman), met December 27, at the offices of Booth, Garret and Blair, Philadelphia, to decide whether or not it was desirable that Committee E should undertake the inspection of the painting of test panels which were to be placed upon a test fence at Atlantic City by the Paint Manufacturers' Association of the United States. By vote of the Sub-Committee Mr. J. F. Walker was also appointed a member and elected Secretary, and the Chairman of Committee E was elected a member of the Sub-Committee, ex-officio.

At the meeting Mr. Heckel, Secretary of the Paint Manufacturers' Association, stated that its object was to duplicate the tests made by Commissioner Ladd upon the North Dakota fence, with the same formulas there used as well as others which the Association wishes to test. Atlantic City was chosen for the exposure in order to get severe condi-

tions due to moist salt air and sand blast action and uneven temperature ranges. Mr. Heckel also stated that the paints for test had already been prepared by the Paint Manufacturers' Association at different factories using linseed oil and driers there on hand. The oil in each case was commercially pure linseed oil.

The Sub-Committee was further advised that the painting was to be upon specially prepared and dried panels of white pine, yellow pine, and cypress, respectively, and that the painting and drying was to be in a room under even temperature in order to avoid the unfavorable winter weather conditions. All of the panels had been given a careful inspection for the Association by a professional lumber inspector, and the effort had been made to get all in as nearly as possible the same condition.

Each paint was to be known only by number, and the test was to be not at all a contest of manufacturers, but was merely to determine any characteristic differences between the different formulas under the special exposure conditions.

It was the wish of the Association that the work of inspection be undertaken by Committee E in order that no question might arise regarding the perfect fairness in the application of the paints.

The fence was to extend north and south. Duplicate panels were to be placed upon each side of the fence, each paint was to be applied to panels of each of the above mentioned woods, and in the painting the weight of the paint applied to each panel was to be carefully determined.

All expenses incurred by Committee E in the inspection would be paid by the Association, including the expenses of the members of the Sub-Committee in attending meetings and inspection trips duly called by the Chairman.

The Association agreed to furnish to Committee E the formula of each paint, with composition of both pigment and drier.

In the course of a thorough discussion of the subject by the Sub-Committee, it was pointed out that under the conditions named by the Paint Manufacturers' Association, Committee E could merely assume to see that the paints prepared by the Paint Manufacturers' Association were applied impartially, giving reports in subsequent inspections as to the relative appearance of the panels. No responsibility could be taken regarding the composition of formulas, nor would the Committee be in position to draw conclusions officially from the results of the exposure.

On this understanding it was voted to accept for Committee E the inspection of the painting, and to recommend to the Chairman of Committee E the appointment of a sub-committee to take charge of the work. A report was made to this effect, and the Chairman of Committee E appointed the same sub-committee to take charge of the matter. Mr. J. H. Parthree of the Wilmington shops of the Pennsylvania Railroad was appointed by the Sub-Committee as its official inspector to be on hand during the entire progress of the painting to see that the work was carried out in a thoroughly impartial manner, and to take the weight of the paint applied to each panel. Mr. Parthree has certified that their conditions

were faithfully maintained throughout the work, and the statement of the weight of paint applied at each coat upon each panel is in the hands of the Sub-Committee.

Three coats were applied to each panel at intervals of about two weeks between each coat, and the panels were finally placed in position on the fence.

A general committee meeting was held at the offices of Booth, Garrett and Blair on January 31, 1908, and one inspection trip was made by the Sub-Committee on May 5; another is planned during the progress of the annual meeting of this Society in June and others thereafter, as often as may seem desirable to the Sub-Committee. It is hoped that in the course of the annual meeting, the fence will be visited by the members of Committee E and by all who are interested in the test.

The formula and composition for each panel, with key, has been furnished each member of the Sub-Committee, and one of the cans of each paint and each japan used, is in charge of the Chairman, in case checking any analysis should seem desirable. Also, to facilitate the work of inspection, blanks have been printed, as per sample herewith, to be filled out by each member of the Sub-Committee for each panel, at each inspection trip.

At the request of the Sub-Committee, the Paint Manufacturers' Association will also institute a series of check tests in which the white-paint base of each formula used will be applied in triplicate at three different rates of spreading, using the same oil and the same thinner in each case.

Also, after the exposure tests are finished, the most durable formula is to be taken, the drier varied, and exposures made.

A report has recently been printed by the Scientific Section of the Paint Manufacturers' Association, giving a detailed statement regarding the test fence. In that report an inaccurate statement appeared regarding the connection of Committee E with the tests. The matter was brought to the attention of the Paint Manufacturers' Association at our inspection trip on May 5, and a corrected statement to accord with our present report was prepared and given to the Association, which agreed to publish it in the form of a slip to be sent to every person to whom their report had been sent. In the future any statement issued by the Paint Manufacturers' Association concerning the work of Committee E will first be submitted to the Sub-Committee for approval. In this manner it will be possible to avoid inaccuracies.

The Sub-Committee believes that valuable indications will be given through this work of the Paint Manufacturers' Association, and it is hoped that at a future time Committee E may be in position financially to supervise throughout a similar test in order that the entire operation including the preparation of the paints, and all details, may be wholly under control which will be recognized everywhere as thoroughly disinterested, as well as scientific.

(Signed) ROBERT JOB,
Chairman.

The report of this Sub-Committee clearly defines the position of Committee E in this series of tests. Committee E's supervision extends only to seeing that these paints are applied in a fair and impartial manner following the method adopted by Prof. Ladd in the North Dakota series of tests, and includes the inspection of the panels at the subsequent inspections.

As the Committee did not determine the formulas on which the paints were made, nor follow the manufacture of these paints, our responsibility covers only the application and subsequent inspection.

A set of tests similar to the series started at Atlantic City is being carried on at Pittsburg. The results from these two separate investigations, together with the results now being obtained from the test fence erected by the Paint Manufacturers' Association at Fargo, North Dakota, will undoubtedly give this Committee some very valuable indications for further investigation along these lines.

Respectfully submitted on behalf of the Committee,

S. S. VOORHEES,
Chairman.

J. F. WALKER,
Secretary.

APPENDIX I.

PAINT ANALYSIS.

BY PERCY H. WALKER.

The series of paints with which this paper deals were all intended as protective paints for iron and steel. The samples were delivered at the laboratory in three lots, the first lot, Nos. C 3476 to C 3492, inclusive, were received May 8, 1907. The second lot, Nos. 3677 to 3697, inclusive, were received August 7, 1907, and the third lot, Nos. 3913 to 3932, inclusive, were received November 2, 1907. Labels on the cans indicated that the samples were all drawn between the middle of August and the middle of October, 1906. The first lot was completed August 10, 1907, the second lot, October 2, 1907, and the third lot January 10, 1908. About seventeen months, therefore, elapsed from the time of taking the sample until the completion of the analyses.

The samples as received were in quart Mason jars and as a rule were in apparently good condition. The jars were handled with as little shaking as possible and notes were made as to condition when received. The jars with their contents were weighed and when possible, the clear vehicle was drawn off. The jars were then again weighed, the contents transferred to other vessels, the jars wiped out and again weighed. These weighings gave the data necessary to figure the original contents of the jars.

The methods of analysis were in the main alike in all three series, but some modifications were suggested as the work progressed, and the methods used in the second series were more satisfactory than those used in the first, and those used in the third series were better than those used in the second. In the tables, Plates I, II and III, "(a)" gives the description of the samples as received in the laboratory, and the percentages of vehicle and pigment. These were determined by treating a portion of the well mixed residue left after drawing off as much as possible of the vehicle, with solvents. A continuous extraction apparatus was not used but the pastes in amounts varying from 7 to 75 grams were shaken with the sol-

vents, allowed to settle, the solvent decanted and the residue shaken with a fresh portion of the solvent. At first four portions of about 250 c.c. each of 88° gasoline were used to extract the vehicle. Samples 3476-84-85-86-87-88-89-90-91 and 92 were treated with this solvent alone. The other samples were treated with gasoline as above and then washed once with benzol and once with ether. Attempts were made to extract first with ether but the pigment does not settle and it is generally better to begin with gasoline and then use benzol and ether. With gasoline the first settling usually takes about twelve hours, the subsequent settlings being more rapid, usually less than two hours when using gasoline, but settling with other solvents always takes more time than with gasoline. Samples 3481, 3484, 3485 3683, 3684, 3685, 3692, 3693 and 3694 were not sufficiently settled to draw off any vehicle. The samples were thoroughly mixed and samples taken for the extraction. Nos. 3683, 3684, and 3685 were all liquid; the others all contained pigment in amounts varying from 10.9 per cent. to 77.9 per cent. Samples 3922 and 3926 were dry colors.

Where separation was possible the amounts of vehicle secured varied from 45 to 363 grams. In some cases this was clear, and in others more or less cloudy. In the first series volatile oils were determined by simply distilling amounts varying from 41 to 108 grams. The apparatus used was a 200 c.c. Jena glass Erlenmeyer flask which was connected with a vertical condenser by a tube bent twice at right angles, all connections being made of cork. The Erlenmeyer flask was suspended in a small air bath carrying a thermometer and heated by a Bunsen burner. The distillation was carried on until no further liquid came over when the thermometer in the air bath registered 190° C. The volatile liquid was caught in a small weighed separatory funnel which was held on the bottom of the condenser by a cork having a small notch cut in it to act as a vent. The volatile liquid in the separatory funnel was weighed and allowed to settle clear, the small amount of water was then drawn off and the funnel was again weighed. The remaining volatile oil was subjected to the tests indicated in the tables. In calculating the percentage of mineral oil from the unpolymerized residue it was assumed that 6 c.c. of pure turpentine would show not more than 0.2 c.c. of unpolymerized residue. These percentages are, of course, only rough approximations.

ANALYSIS OF BRIG. INTS. I

General Information										Detailed Data										Summary Statistics										
No.	Loc.	Time	Character	Direction	Velocity	Size	Color	Shape	Texture	No.	Loc.	Time	Character	Direction	Velocity	Size	Color	Shape	Texture	No.	Loc.	Time	Character	Direction	Velocity	Size	Color	Shape	Texture	
1	1	10	Weak	10	10	10	10	10	10	1	1	10	Weak	10	10	10	10	10	10	10	1	1	10	Weak	10	10	10	10	10	10
2	2	20	Strong	20	20	20	20	20	20	2	2	20	Strong	20	20	20	20	20	20	20	2	2	20	Strong	20	20	20	20	20	20
3	3	30	Medium	30	30	30	30	30	30	3	3	30	Medium	30	30	30	30	30	30	30	3	3	30	Medium	30	30	30	30	30	30
4	4	40	Weak	40	40	40	40	40	40	4	4	40	Weak	40	40	40	40	40	40	40	4	4	40	Weak	40	40	40	40	40	40
5	5	50	Strong	50	50	50	50	50	50	5	5	50	Strong	50	50	50	50	50	50	50	5	5	50	Strong	50	50	50	50	50	50
6	6	60	Medium	60	60	60	60	60	60	6	6	60	Medium	60	60	60	60	60	60	60	6	6	60	Medium	60	60	60	60	60	60
7	7	70	Weak	70	70	70	70	70	70	7	7	70	Weak	70	70	70	70	70	70	70	7	7	70	Weak	70	70	70	70	70	70
8	8	80	Strong	80	80	80	80	80	80	8	8	80	Strong	80	80	80	80	80	80	80	8	8	80	Strong	80	80	80	80	80	80
9	9	90	Medium	90	90	90	90	90	90	9	9	90	Medium	90	90	90	90	90	90	90	9	9	90	Medium	90	90	90	90	90	90
10	10	100	Weak	100	100	100	100	100	100	10	10	100	Weak	100	100	100	100	100	100	100	10	10	100	Weak	100	100	100	100	100	100
11	11	110	Strong	110	110	110	110	110	110	11	11	110	Strong	110	110	110	110	110	110	110	11	11	110	Strong	110	110	110	110	110	110
12	12	120	Medium	120	120	120	120	120	120	12	12	120	Medium	120	120	120	120	120	120	120	12	12	120	Medium	120	120	120	120	120	120
13	13	130	Weak	130	130	130	130	130	130	13	13	130	Weak	130	130	130	130	130	130	130	13	13	130	Weak	130	130	130	130	130	130
14	14	140	Strong	140	140	140	140	140	140	14	14	140	Strong	140	140	140	140	140	140	140	14	14	140	Strong	140	140	140	140	140	140
15	15	150	Medium	150	150	150	150	150	150	15	15	150	Medium	150	150	150	150	150	150	150	15	15	150	Medium	150	150	150	150	150	150
16	16	160	Weak	160	160	160	160	160	160	16	16	160	Weak	160	160	160	160	160	160	160	16	16	160	Weak	160	160	160	160	160	160
17	17	170	Strong	170	170	170	170	170	170	17	17	170	Strong	170	170	170	170	170	170	170	17	17	170	Strong	170	170	170	170	170	170
18	18	180	Medium	180	180	180	180	180	180	18	18	180	Medium	180	180	180	180	180	180	180	18	18	180	Medium	180	180	180	180	180	180
19	19	190	Weak	190	190	190	190	190	190	19	19	190	Weak	190	190	190	190	190	190	190	19	19	190	Weak	190	190	190	190	190	190
20	20	200	Strong	200	200	200	200	200	200	20	20	200	Strong	200	200	200	200	200	200	200	20	20	200	Strong	200	200	200	200	200	200

1. Weak
 2. Strong
 3. Medium
 4. Very Weak
 5. Very Strong
 6. Very Medium
 7. Very Weak
 8. Very Strong
 9. Very Medium
 10. Very Weak
 11. Very Strong
 12. Very Medium
 13. Very Weak
 14. Very Strong
 15. Very Medium
 16. Very Weak
 17. Very Strong
 18. Very Medium
 19. Very Weak
 20. Very Strong

At first the plan used in the first series was followed in the second series, but it was found that though fairly good results were obtained when the vehicle contained large amounts of volatile oils, very bad results were obtained where little volatile oil was present. This throws a good deal of doubt on the percentage of volatile oils in the first series, the figures being probably low. The method then followed was to distil about 25 grams in a current of live steam, using a 500 c.c. round-bottom flask with a spray trap between the flask and condenser. Distillation was continued until 100 c.c. of water had passed over. The oils were then separated from water and weighed and 0.3 gram added, a correction arbitrarily chosen for the oil dissolved in the water. The testing of the volatile oils was done on the mixed oils obtained from dry and steam distillation, using, of course, different portions of the vehicle; but in examining the non-volatile portion, the residue from the dry distillation alone was used. In this series there are six samples which had not settled; in these the volatile oil was determined by steam distillation.

In the third series the determination of volatile and non-volatile in the vehicles was effected by a method which is better than any used in the first two series. Amounts varying from 27 to 79 grams were weighed into a 500 c.c. round-bottom flask connected with a condenser by means of a spray trap. A current of live steam was passed through until 100 c.c. water collected in the receiver the oils were separated from water, weighed, and the same correction (0.3g.) applied as in the other steam-distillation method. After driving off the volatile oils the steam was cut off and air drawn through. At the same time the flask was heated to 130° C. In about 15 minutes all water was driven off and the residue was used for testing the non-volatile portion. Only three samples (3930-31-32) of the third series were subjected to dry distillation, and these were so treated in attempting to determine acetone, which, while it was indicated by shaking the paint with water and getting the iodoform test on the watery solution, could not be quantitatively determined, since no distillate could be recovered even on heating to 190° C.

The tables of analyses show clearly what was done with the non-volatile portion of the vehicle. In the first series saponification numbers were determined on several of the samples. In the last

two series this was not done, but the unsaponifiable matter was determined instead.

In the analyses of the pigments in the first series the samples were treated with hydrochloric acid (1:1), filtered on a weighed paper, dried at 105° C., and weighed. The residue was then ignited and again weighed. The loss on ignition was called carbonaceous matter.

In the second and third series a different plan was followed. One portion was weighed out and the loss at 105° C. determined. This was then ignited and again weighed. The second loss would be combined water, carbonaceous matter, CO_2 , etc. Another portion was treated with hydrochloric acid, filtered on a Gooch crucible, dried at 105° C. and weighed. This was then ignited and the loss was called "carbonaceous matter." This subtracted from the total loss gives the "loss on ignition less carbonaceous matter weighed as such."

The rest of the results were obtained in the ordinary way. In the first and second series the lead was assumed to be as red lead and calculated as Pb_3O_4 except in No. 3483 where it is calculated as lead sulphate and white lead, the sulphate being figured from the SO_3 found, and the remaining lead calculated as basic carbonate, a qualitative test showing CO_2 .

In the third series, Nos. 3913 to 3921, inclusive, the lead is calculated as PbO . In Nos. 3922 to 3932, inclusive, lead is calculated as Pb_3O_4 . On the red lead paints, Nos. 3922 to 3929, inclusive, in addition to determination of total lead, which for the summation was calculated as Pb_3O_4 the amount of actual Pb_3O_4 was determined by titration of iodine liberated from KI by the pigment in the presence of large excesses of sodium acetate.

It must be confessed that these analyses do not give the information desired. We can with reasonable certainty decide whether the volatile oil used was turpentine or mineral oil, we can come to a fairly good conclusion as to the composition of the pigment, though even here we are frequently left in the dark. For example, we cannot say whether the magnesium silicate found was of an abestos or talc nature. These, however, might possibly be determined by the microscope. On the whole, for determining the general nature of the inorganic pigments and the volatile oils used, chemical analysis is fairly satisfactory. The carbonaceous

matter present, however, may be due to carbonaceous matter in the original pigment or it may be due to unextracted vehicle. In No. C 3476 the pigment was red. It appeared to have no carbon, but the analysis shows 10.44 per cent. carbonaceous matter. In this case this carbonaceous matter was due to unextracted vehicle (gasoline only was used in washing out the vehicle). Now what was the nature of this unextracted vehicle? Was it linxyn? From the fact that we have nearly 10 per cent. of red lead present and the remainder is nearly all oxide of iron it is certainly possible. Was it gum? A varnish instead of a straight oil might have been used. From the information available concerning this sample we learn that the last hypothesis is probably the correct one; but it must be confessed that from the chemical data alone we really cannot decide. If we take the cases, however, of the dark colored pigments where some carbonaceous matter is evidently present in the pigment, we certainly cannot say that all of the carbonaceous matter found was derived from the original pigment. While as has been shown the interpretation of the analyses of extracted pigments often presents great difficulty, the interpretation of the analyses of the non-volatile portion of the vehicle is much worse. I must confess that an attempt to draw any conclusions from these analyses is very discouraging, in spite of the large amount of work done. Perhaps it would have been better had we subjected all samples to an analysis adapted to varnishes with the idea of determining the gums present. Such analyses are at best unsatisfactory and we were also of the opinion that most of the samples would at any rate be straight oil paints. The specific gravities of the total vehicle and, in the last series, of the non-volatile portions were determined with a pyknometer. This was a mistake. A Westphal balance should have been used and would have practically eliminated the error due in some cases to the small amount of pigment which did not settle out. In some cases these analyses can be interpreted as indicating pure linseed oil, as, for example, No. C 3483; but in other cases this cannot be done. Consider No. 3482. From the ash, saponification number and specific gravity (which by allowing for the 18 per cent. of light oil found in the vehicle would be about 0.935 for the non-volatile vehicle) would indicate pure linseed oil; but the iodine number is low. We know though that on mixing with lead compounds the iodine

number of linseed oil is sometimes lowered very much. We also know that some linseed oils have a specific gravity above 0.935. Now is this a pure linseed oil which has had its iodine number lowered by being in contact with lead carbonate and sulphate, or is it a mixture of linseed oil with other fatty oil? I must confess I cannot say.

This paper is presented with a hope that it will lead to a discussion of the interpretation of paint analysis. I wish to express my thanks to the Assistant Chemists in the Contracts Laboratory, Messrs. F. W. Smither, H. C. McNeil, and E. W. Boughton, for their skilful and careful work in completing this long series of very complex analyses. These gentlemen did all the analytical work.

ANALYSIS OF BRIDGE PAINTS—1

Panel No.	Cat. No.	ELEMENT										Kottstörfer Figur.										Volatility		Remarks.		
		Percent of Pigment.	Percent of Oil.	Percent Volatile.	White Lead percent.	Red Lead percent.	Sulphate of Lead, percent.	Zinc Oxide, percent.	Linseed Oil, percent.	Silica, percent.	Clay, percent.	Oxide of Iron, percent.	Graphite, percent.	Carbon, percent.	Barites, percent.	Silicate, percent.	Gypsum.	And Filler.	Percent Unabsorbable.	Hard Game.	On Vehicle.	On Non-Volatile Oil.	On Solvent.		Flash at 10° C.	Refractive Index at 25° C.
1	1	30.8	46.5	10.7		9.88					7.84							11.0	16.2	11	15.8	135.9	No	1.4063	Turps.	
1	2	26.8	64.8	15.4		5.28					53.06	59.3						12.3	15.0			115.8		1.4041	"	
2	1	33.3	55.6	10.9					41.18		17.00	14.60						12.4	....			179.8	Yes	1.4164	Turps. and benzine.	
2	2	30.9	51.4	8.7					39.20		16.66	41.2						14.4				136.1		1.4142	"	
2	3	30.0	53.7	9.1					35.10		10.94	7.2						16.4				180.3		1.4171	"	
3	1	6.0	46.5	46.6														1.0					No	1.4053	Turps.	
3	2	62.5	25.1	9.1	7.4		15.81	25.66			11.8							4.0				140.3	125.3	Yes	1.4470	Turps. and benzine.
3	3	48.3	49.3	2.4							33.80						64.76	1.1				157.2	180.2	No	1.4560	Turps.
4	1	14.0	60.1	25.7		4.46						61.86													1.4652	"
4	2	7.2	71.2	20.6		4.58						72.24						5.4				....			1.4650	"
4	3	15.2	59.6	25.2		2.40						88.22						8.3				125.5	178.7		1.4633	"
5	1	52.0	44.2	3.8	....	22.04						68.26						13.2				176.0	161.3	Yes	1.4527	Turps., benzine and camph. oil.
5	2	47.5	45.6	6.0		28.50						68.70						8.8				174.9	201.5		1.4405	"
5	3	50.7	46.7	2.6		27.38						66.62						8.3				169.5	179.0		1.4482	"
6	1	61.1	35.7	3.2		71.53				19.22			....					21.8				135.4	149.6	No	1.4101	Turps. and benzine.
6	2	60.2	34.9	4.0		5.91				13.20		21.40						16.6				144.8	165.3			"
6	3	34.0	57.7	8.3								78.85						8.1				168.6	182.0	Yes	1.4593	Turps. and benzine.
7	1	52.0	42.3	4.0					28.16		21.53	36.51						6.8				171.1	190.9		1.4226	Turps. benzine and camph. oil.
7	2	52.8	41.1	6.1					20.98		24.61	49.60						8.1				168.7	166.0		1.4263	"
7	3	52.8	41.7	5.5					27.81		20.13	41.94						6.8				161.5	186		1.4210	"

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ANALYSIS OF BRIDGE PAINTS—II.

		PIGMENT															VEHICLE											
Panel No.	Coat No.	Per cent. of Pigment.	Per cent. of Oil.	Per cent. Volatile	White Lead, per cent.	Red Lead, per cent.	Sulfate of Lead, per cent.	Zinc Oxide, per cent.	Lithop. no. per cent.	Silica per cent.	Clay, per cent.	Oxide of Iron, per cent.	Graphite, per cent.	Carbon or Lampblack per cent.	Barites, per cent.	Slate, per cent.	Gypsum	Asst Figure	Per cent. Unsaponifiable	Hard Gums	Koettstorfer Figure			Flash at 3° C.		Refractive Index at 25° C	Volatile Residue	
																					On Vehicle	Oil Non-Volatile Oil	On Saponifiable Oils	Flash at 3° C.	Refractive Index at 25° C			
8	1	33.7	57.4	8.0									07.82					0.0				100.0	181.1		No	1.4560	Turps.	
8	2	31.8	50.5	8.7									05.73					7.2				107.0	102.3					
8	3	34.8	50.3	8.9									06.84					3.0				101.5	187.6		No	1.4549	Turps	
0	1	40.4	50.4	3.2									10.16			8.70		4.0	0.69			146.7	154.9	147.7	Yes	1.4288	Turps and benzene	
9	2	38.4	58.4	3.2					....				31.82	....	....	70.10		5.4				103.0	172.9				
9	3	26.5	71.0	3.0					....				41.0	....	....	53.39		7.3	4.99			103.0	108.8	172.0	Yes	1.4344	Turps and benzene
10	Dry Pigment				100.00																							
10	1	74.8	24.6	0.6		100.00												22.0	0.70			100.0	158.2	169.2				
10	2	65.8	23.0	0.3		100.00												22.4	1.05			107.0	100.0	177.2				
10	3	58.3	41.1	0.6		100.00												32.6				150.0						
11	Dry Pigment				100.00																							
11	1	78.8	20.9	0.3		100.00												7.1				100.0	102					
11	2	77.3	22.4	0.3		100.00												7.2	....			100.0	113		No	1.4035	Turps.
11	3	76.5	23.4	0.1		100.00	....											8.7				100.0	188.0				
12	1	54.6	42.4	3.0	18.04		....	12.2					16.14	....	47.10			2.7				100.0	188.0				
12	2	66.0	30.3	3.1		13.77	....						81.1					1.8							No	1.4637	Turps
12	3	71.88	3.4		14.55								88.5					11.0	....	....						1.4648	
13	1	49.9	44.7	5.4					....		57.90	8.17	24.2					1.0	....			174.9	105			1.4453	
13	2	51.2	43.2	5.6					55.80	9.78	27.70					5.8				167.1	188.8					
13	3	46.4	45.1	5.5					50.20	17.3	30.00			7.0				175.5	196.9	No	1.4770			

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ANALYSIS OF BRIDGE PAINTS—III

Panel No.	Coat No.	Percent of Pigment			White Lead, percent	Red Lead, percent	Sulphate of Lead, percent	Zinc Oxide, percent	Lithium, percent	Silica, percent	Clay, percent	Oxide of Iron, percent	Graphite, percent	Carbonaceous Matter, percent	Rust, percent	Sulphate of Zinc, percent	Gypsum, percent	Acid, percent	Free Alkali, percent	Hardness	Kettner's Test			Remarks				
		Oil	Oil	Oil																	On Vehicle	On New Vehicle	On Old Vehicle	Temperature, °C.	Relative Humidity, %			
14	1	77.4	21.4	1.2	76.60						18.40							27.7	8.7		156.7	165.6	171.6			Turps		
14	2	86.8	8.7	1.7									89.66					8.6			228.6	236.6		No	14067			
14	3	84.88	6.6										95.50					7.2			175.1	188.6						
15	1	17.7	46.3	36.0									99.38													Yes	14410	Benzene
15	2												99.52															
15	3												99.12															
16	1	25.5	59	14.2									77.66		46.1			7.3			49.5	187.1					14267	Turps and benzene
16	2	28.7	58.2	13.3									48.14		47.7			7.7			148.6	182.2						
17		25.5	54.2	12.2									51.62		11.48			6.2			144.9	191.1						
17	1	31.8	37.8	7.4									7.84	34.61				1.9			166.3	202.3		No	14670		Turps	
17	2	35.5	37.3	4.4									6.39	39.9				7.1			174.6	196.8						
17	3	35.5	37.6	5									1.46	46.6				5			71.8	201.9		No	14693		Turps	
18	1	13.7	8.2	1.7														14.4			100	238.7		Yes	1468		Turps and benzene	
18	2	14.7	8.7	4									1.72								78.2	197						
18	3	15.2	8.7	1.7									78.06					15.3			158.4	166.3						
19	1	11.4	8										6.8					8			100	237.8		No	14410		Turps	
20	1	17.4	7.7	7.1									3.7					4.4			181.6	189.7						
21	1	16.8	6.6	5	4.84													5			117.1	121.8						

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APPENDIX III.

SUPPLEMENTARY REPORT OF THE DIRECTOR OF TESTS.

The application of the paint was completed on October 15, 1906, and all data required by the Committee was submitted by the Director of Tests on a tabulated sheet for each separate manufacturer's protective coating. In answer to the Committee's request for descriptive notes as to conditions and incidents relating to the work, the following supplementary report is respectfully submitted:

The structure had been completed but a few months, and the painting was the first following the shop and erection coat. For the test the panels were numbered from west to east, making twenty panels for the two spans, and Panels 1 to 19 were used for the tests. Panel 20 was turned over to the contractor as his regular work, and his paint was applied on Panel 20 at the same time as that of the test on Panel 19. The division of the panels for the tests was so made that each of the 19 tests was applied to a full panel cross section of the bridge, but in order to give each test a full truss-post the dividing line was drawn half way between posts.

As the Committee required each test to be made with three coats, while some of the manufacturers asked for a test of two coats only, a compromise was made by painting the entire down stream half of the 19 panels, three coats, and allowing two coats *only* on the up stream half of such panels as the manufacturers requested.

For cleaning the arrangement of staging and men was as follows:

1. Two men, on planks that were extended from floor beam to floor beam, for cleaning the upper work between stringers and between top chords and stringers.
2. A four man staging was worked in each panel between floor beams from the top of floor beams down to the bottom horizontal bracings.
3. Two men on a plank suspended below the bottom chords from truss to truss, moving the plank forward as work progressed.
4. Two men on the outside of the top chord on a plank slung from the outside guard timbers.

The brush men followed on the same kind of stagings except that all the top work was painted from the four man, track suspended, staging. Unfortunately, this arrangement of stagings required the application of two different tests at the same time on the same four man staging, one from each end; and as the areas to be covered were not uniform, one end crew would have more surface to cover than the other. This, in a measure, makes void a comparison of time and areas covered, and furnished encouragement for a man to slight his work in trying to keep up with the other men.

From the beginning of preparations in June, 1906, to September 1, 1906, when work had advanced as far as the cleaning of Panels 1 to 7, and the application of the first coat on Panels 1 to 6, Mr. F. H. Cubberly, from the Philadelphia Department of Bridges, was in charge as Director of Tests. His leave of absence expiring on September 1, the writer assumed the position, taking over the work and continuing it without interruption, except from weather conditions, until completed. The brush work on the bridge was completed October 15, 1906, and the triple sets of test plates were, on November 1 to 3, placed for exposure by fastening them securely in a strong framework that had been previously bolted on the top of the bottom chord of the down stream truss. Each coating-test plate was placed in a vertical position with a southeasterly exposure in its respective bridge-panel.

The Director, after September 1, did not find it necessary to delay the brush work and use the stagings for inspection, but was almost constantly with the men. For both cleaning and brush work he was able to point out errors as the work advanced, and the men were sent back or the staging changed at once to correct these errors. This practice, with the point gained by keeping each man on his particular part of the work, soon put the entire force in line, and while the work was not up to the Committee's anticipated point of theoretical execution, the result was above the average of that attained in general railroad bridge painting. Occasionally, paint was spilled on work partly dry or men used tools not as directed; some in hurrying to keep up with the other better man did not brush out their work well, especially where the mixture worked stiff and the experienced man was better able to do quick work well. In this connection it was demonstrated that a section painted with a stiff mixture appeared uneven and poorly done, when with a light easy flowing mixture a more even and better class of work could be done, regardless of any effort the Director might make to prevent bad work. The above is equally true with regard to the work of different men cleaning the steel.

Weather observations were recorded at the hours designated. If humidity conditions were close to the limit, frequent observations were taken. Sudden light showers would call for a halt on account of excessive humidity and if the reading returned to the safe limit but moisture could be found on the steel by a handkerchief test, work was delayed until no moisture remained. However, it must be admitted that applying paint on days when the humidity is close to the limit and on other days when the air is clear and dry is not a good procedure for comparative tests.

"In the course of application of each individual sample the Director shall obtain from the workmen general information as to the working qualities of the paint, as well as such other particulars as may suggest themselves to him as useful. In each instance he shall also note particularly the rate of drying and the physical appearance of each coat."*

Opinions expressed by the brush men were contradictory and condi-

* Instructions to the Director of Tests. See Vol. VI., p. 53.

tions were such that no attempt at a comparison of working qualities was made. This can best be taken from the notes of the plate test, made by the Committee's experts from the same paint that was being applied on the bridge.

Before the hour for starting work each morning the Director passed over the bridge and examined the steel for moisture or other irregular conditions. Then the weather records were taken and if conditions were right the foreman was signaled to come for paint. The paint was weighed out to the men in regular brush pots ready for use, marked with metal tags, the Director following the pots to their respective panels, and when work stopped or changed the pots and brushes were returned to the store-room and properly cleaned. Where round pound brushes could not be used flat lamb's-wool swabs were permitted and on the inside of bridge seat chairs and the inside of top chord box girders double round pound brushes on long handles were used.

"The painting of the check panels provided for the Committee shall be under the general supervision of a competent and expert painter but the Director shall make careful note of all details in regard thereto in connection with his notes on the general work."

The steel plates used were prepared as directed and were handled entirely by the expert painter and his assistant. The work of cleaning the plates was done in a shanty near the bridge and the paint applied in another room fitted up exclusively for this work. The paint store-room was a third shanty near the others and all were so arranged that the Director could know that the work was properly done without taking his attention from the bridge work.

The instructions from the Committee's letter of July 30, 1906, were carefully followed.

The steel was cleaned by the advance gang of six men on the stagings as previously noted. First a sharp-edged steel chisel, about $1\frac{1}{2}$ ins. wide, and long enough to be used by both hands if desired, was used to remove everything loose. These chisels were kept sharp and did good execution. After the chisels a very stiff steel wire brush was used to remove the rough loose paint that was left behind the chisels and also to brighten up the rusty surfaces. As is usual in large bridges, the condition of the steel surface varied from a smooth, hard black-oil shop-coat finish on most of the beams and top-chord members to a rough sticky, heavily-coated black-paint surface on nearly all of the eye-bar members of the trusses. The eye bars had evidently been stacked up when the paint was wet and in separating them the paint had either peeled off in a few spots or the wood had adhered in a few places to the steel. Many of the eye-bar members, although painted months before, were (in warm weather) still sticky, and if rubbed with the stiff wire brushes became rough but could not be cleaned by any manipulation of the chisel or brush. Only fire or the sand blast would have cleaned the steel entirely of paint and rust. This condition was also true of a few of the 5-ft. floor beams. These

members were gone over with the sharp chisels only, and the first coat of our paint brushed on over the soft shop coat. In general the top and bottom surfaces of the small horizontal members had entirely lost the shop coat but the surface rust had not become rough from scales. The truss posts and some of the bottom chord members threw off scales of paint and rust under the chisels, showing plainly that the shop coat had been applied under bad conditions. Many of the built members showed a shop coat of black on the plates with red lead under the flange and stiffener angles. Red lead had also been freely used in erection, on the bridge seat chairs and pin connections. The top chord (box girder) had also received a good coating of red lead on the inside. Also, before tracklaying, the upper surface of all top members had been painted, according to the Company's standard requirements, with red lead paint and we were required to do no top surface work. Also, complying with the Committee's final instructions, the inside cleaning of box girders and posts was omitted. Bottom chord members were cleaned (where close together) only by such chisel work as was possible and these surfaces are not a part of the comparative test. The use of the long handle brushes in the top-chord box girders was very unsatisfactory. Much paint (of the light mixtures) was lost by dripping from the brush although some of the men were expert and did good work. After the first coat these surfaces were not painted and no long handle brushes were used as these members had been well painted inside before erection. These conditions are pointed out to indicate the obstacles which prevent uniform work on a structure of this class by the average gang of bridge painters in the regular course of work. We can, however, claim to have done as nearly uniform work and to have painted our part of the structure in as thorough a manner as can be expected under present-day conditions. In considering the different sections, it should be remembered that the tabulated data sheets show that the steel was not in a uniform condition. The amount of rust and scale increased towards the east, due undoubtedly to the fact that yard engines in switching came on the bridge from that end. Also, during the progress of our work construction trains loaded with ashes were switching on the east end and not infrequently showered a fresh coat with water or ashes. It was noticed that although no visible signs of grease had been observed before the first coat was applied, still on some sections after the first coat began to dry, there was unmistakable evidence that the inside of the track stringers directly under traffic, were spattered with grease, probably from passing trains or the jolt of an engine stopping on the bridge. This was observed on two sections and noted on the data sheets.

Weather conditions also prevented uniform results. In one instance, paint was applied on two adjoining sections until five o'clock p. m. under correct weather conditions, but a driving storm came on and while one paint held and was not considerably injured, another, a slow drying paint was badly washed and also injured the fresh paint of the adjoining panel by washing down upon it along the batter post and truss diagonals.

The Director endeavored to follow the Committee's written instructions so far as the average conditions and the skill of the workmen could be made to conform to them. If his interpretation was more practical than some of the members may have desired it must be remembered that only the inside work on the test plates was by skilled workmen and under conditions that were wholly within the Director's control.

From these plates all conditions of spreading and drying rates and nature and condition of film should be determined. After September 1, the contractor and his men gave the Director loyal support in the practical execution of the work, under the Committee's instructions, as they had at that time been interpreted, striving so far as possible, to make the work uniform and to give each coat the same handling, and at the same time to proceed with the job in a manner that could be considered consistent for general first-class work. The bridge work should be judged as a practical test that was attended with the usual accidents and incidents on such work, but with more than the usual care regarding weather conditions and correct brush work. The Director's inspection of the completed work indicated that panels painted with the light easy flowing mixtures were more evenly coated and gave evidence of better results than some of the heavier pigments which had what appeared to be a first class vehicle forming a stiff mixture hard to apply. It is equally true that the only trouble caused by the second or third coat breaking away when applied on very cold steel came from what appeared to be the highest-grade heavy-weight paints.

The data sheets give information as to conditions of steel and show the preparation of the surface to have been not the smooth surface free from the black-oil first coat, as had been the Committee's first expectation.

If the element of personal equation (good or bad work) could be eliminated from our field work, it might be profitable to note the comparison in service between the bridge work on a very bad steel surface and on that of the same paint on test plates being exposed to the same weather conditions. Conditions were such, however, that it is not possible to determine whether peculiar conditions of color, surface, texture or apparent brush marks that might be observed by a careful inspection of the bridge, are due to a failure of the mixture to fulfil the requirements of a good protective coat, or to the fact that this particular condition was caused by one of the many possible accidents or incidents noted in connection with the work. Speaking broadly, the experience of the Director impressed him with the belief that users and manufacturers of protective coatings cannot expect positive or uniform results in the field work while the present careless practice in applying shop coats continues, and that until a successful machine method of applying paints can be found to replace the present uncertain hand labor application, the best mixture will not always produce the best protection.

Respectfully submitted,

HOBERT B. POTTER,
Director of Tests

Bulletin No.

10

PROPERTY OF
DODGE & DAY
MUST BE RETURNED.

**Protective
Coatings for
Conservation of
Structural
Materials**

By R. S. PERRY

**Scientific Section
Paint Manufacturers' Association
3500 GRAYS FERRY ROAD
PHILADELPHIA, PA.**

WITH ACKNOWLEDGEMENTS TO AND
DELIVERED BEFORE THE
AMERICAN CHEMICAL SOCIETY
BOSTON, MASSACHUSETTS
JANUARY 22, 1909

**Protective Coatings for
Conservation
of
Structural Materials**

By R. S. PERRY

Published by
**Scientific Section Paint Manufacturers'
Association of the United States**
3500 Grays Ferry Road
PHILADELPHIA, PA.

(Announcement of this Paper by the American Chemical Society)

American Chemical Society

NORTHEASTERN SECTION

Boston, January 15, 1909.

DEAR SIR:—

You are cordially invited to attend the next regular meeting of the Northeastern Section of the American Chemical Society, which will be held on **Friday, January 22**, at eight o'clock, P. M., in Room 6, of the Lowell Building, of the Massachusetts Institute of Technology, at the corner of Clarendon and Stanhope Streets.

SUBJECT:—**"Protective Coatings for Conservation of Structural Material."**

Mr. ROBERT S. PERRY, President of Harrison Brothers & Co., Inc., Philadelphia, Pa., and Director of the Scientific Section of the Paint Manufacturers' Association of the United States, will address the Section.

Professor WILLIAM H. WALKER, of the Massachusetts Institute of Technology, will introduce the subject by stating briefly the fundamental principles underlying the decay of structural materials.

The Scientific Section of the Paint Manufacturers' Association, under the direction of Mr. Perry, is carrying on a most exhaustive and important series of experiments in connection with the question of corrosion and decay, and in view of the importance of the subject, it is hoped that you will be able to avail yourself of this opportunity to attend this meeting and that you will also extend the invitation to any others who may be interested in the subject.

Yours very truly,

KENNETH L. MARK,

Secretary.

CHAPTER I.

VALUE WASTE AND NEGLECT OF STRUCTURAL MATERIAL.

The use of protective coatings to prolong the life of structural material, by protecting the surfaces thereof, dates from our first knowledge of human life itself.

About the base of each pyramid we find the accumulated ruin of the stone casing or coating which originally protected the structural surface of the pyramid.

In the highlands of Peru, great fortifications, old in the days of the Incas, still exhibit similar protective casings.

We read that Noah finished off the ark by painting it "within and without," while the solution of man's first technical problem and his first industrial effort found expression in Adam and Eve's first protective coating of fig-leaves and skins—decorative, perhaps, but, compared to the protective coatings of to-day, somewhat deficient in the requisite qualities of durability—of impenetrability, or excluding power—and in hiding or covering values.

We learn now, with humility, that we have been, in the past, incorporating in many so-called protective coatings—or paints—certain pigments, which, instead of preserving, do actually attack the iron structure beneath. Like poison ivy among Adam's leaves, these can, where present, be held responsible for resulting trouble.

The progressive civilization of the past century has called for a stupendous investment of human effort and of the world's natural resources in structural material, to meet national, commercial and domestic needs.

A century ago, North America, except for a narrow foothold of civilization along its coasts, was a virgin continent, ready to yield its store of timber, coal, limestone

Rapid
Accumulation
of Values in
Structural
Material

The Drain
Upon Our
Natural
Resources

and iron ores to the manifold needs of civilization. That narrow coastline was peopled by those who came under the guidance of Providence, seeking absolute religious freedom. As a natural consequence, they evolved a passionate devotion to the principle and practice of political freedom as well.

Having obtained both, in the fullest measure, for themselves, they have thrown open wide the ports of opportunity to the less favored peoples of other lands; they have offered with lavish hand the natural wealth of this continent, and have freely given to all mankind the opportunity, by industry, to achieve independence and comfort, with religious and political freedom.

The advancing century has seen the outposts of a pioneer civilization pushed westward and northward from the shore of the eastern sea that separated the Pilgrim from his ancestral land.

The frontier town sprang up on the site of lumber and mining camp, and the league-long furrow scarred the virgin prairie. Thus our confines have been pushed beyond the barrier ranges, till they are limited only by the Western Ocean and the Ultimate Cold.

Unrestricted immigration from foreign lands has drawn without stint upon the natural resources of the country—coal, iron, timber, and the bone and sinew of the land itself.

The natural resources of America have paid a price in one century, which may not be too great for so marked an advance in civilization, but a price which is indeed appalling.

Lavishly we have given, lavishly and ruthlessly we have used.

We must no longer take with unstinted and careless hand, but rather study to conserve what remains, whether it be as yet an undeveloped natural resource, or whether it has been utilized and converted as property to the use of present American civilization.

Already national and civic interest has been aroused

for the preservation and increase of our standing timber reserves. But what have we done as a nation political, or a people commercial, to protect and conserve the stupendous values already existing in the planks, timbers, piles, girders and columns of bulkhead, dock or structure already reared?

To the charge of carelessness and neglect, engendered, perhaps, by the apparent boundless store, we, as a nation, must answer "Guilty."

No State of this Union has as yet appropriated a dollar toward the direct scientific problem of arresting the decay of the cellular tissue of the timber now in use, or to arrest or prevent corrosion of structural iron and steel by oxidation or rust.

The national government has not appropriated one dollar to discover the cause of wood decay.

The dawn of a new era is upon us.

Two men, one within the Agricultural Department, in the office of Public Roads, Dr. Allerton S. Cushman; the other within the laboratories of the Massachusetts Institute of Technology, Dr. William H. Walker, have, by brilliant conception and painstaking research, succeeded in proving the vital and essential principles of the reason for the rusting of steel and iron, and the results obtained give us a foothold for further advancement.

The national government has appropriated the sum of \$10,000 for the development of Dr. Cushman's work.

The Paint Manufacturers' Association of the United States has appropriated many times this amount, to be used by its Scientific Section in collecting and verifying data in research work which will place the art, if possible, under control of exact science.

The American Society for Testing Materials, the Carnegie Technical Schools, the Pennsylvania Railroad, various steel companies and the Master Painters' Association have bestirred themselves, through officers and committees, to test the present products for protection, to

The Past Waste
and Neglect of
Structural
Materials

Recent Efforts
to Conserve
Structural
Materials

obtain legislation which will disclose legal knowledge of the nature of these products, and also to suggest and test such materials as may be available.

The National Association of Master Sheet Metal Workers, at their last convention in Buffalo, took up this work, and after discussion adopted a sweeping resolution, condemning certain paint materials for tinned or galvanized iron. *

The American technical world and the American public propose to know what not to use, and how and what they can use to protect structural material.

* Resolution adopted by the Master Sheet Metal Workers at Indianapolis, August, 1906, as follows :

"Too much stress cannot be laid upon the quality of paint—how and when applied. A tin roof should be painted at once ; the paint should be of the best—**GRAPHITE AND COAL TAR PAINTS ARE POSITIVELY INJURIOUS TO TIN AND SHOULD NEVER BE USED.**"

CHAPTER II.

THE NEW SCIENCE OF PROTECTIVE COATINGS FOR STRUCTURAL MATERIAL.

It may seem an exaggeration, and it may be startling, but it is a fact that the science of making protective coating first stepped over the threshold of the nursery after the Civil War, and that, despite laboratories in the establishments of the great paint manufacturers, it has been largely a rule of thumb art until within the past two years.

Protective
Coatings
Have been a
"Rule of
Thumb" Art

The science and technical art of protective coatings are only just ready to emerge from a practice and commerce based upon accumulated human experience and results gathered haphazard, and not evolved by cold-blooded scientific analysis and deduction, nor subjected to unprejudiced test and proof; in other words, the making of protective paints is at the point where the art of making iron and steel stood when Sir Henry Bessemer, Andrew Carnegie and contemporaries brought into the business, scientific men and laboratories.

These revolutionists in the iron and steel industry did not destroy that which went before, but, passing to the new, they carried with them all that experience could give them.

This is the only safe way in which a truly efficient science of protective coating can be evolved without great loss of values and danger of error, together with loss of public confidence.

Difficulties
of the
New Science of
Protective
Coatings

On the one hand, the paint theorist who insists upon his ideas, regardless of past experience, in the work of protecting structural surface, must be restrained.

On the other hand, the practical paint man who cannot generalize from his mass of data, who, in other words, "cannot see woods for the trees," and who ignores the factor of variable conditions in testing and investigating, will prove the same conservative that in the iron business retarded laboratory control at the blast furnace and the era of formula and specification iron and steel.

Another conservative force will be "vested interest" entrenched behind a business built upon the production of a so-called protective coating containing material really harmful, even destructive, to iron or steel. Such cannot be expected to welcome the new era of scrutiny and test.

Every new technical art and science must have some point of beginning, some definite basis from which to start, a definite purpose to be achieved, and recognized laws or limitations, however crude, under which it shall start its work.

With all honor and deference for the learned investigations of individual scientists, with full acknowledgment of the valuable results heretofore obtained along this or that special line of endeavor, with eager recognition to those who have exhaustively studied the relation and behavior of this or that material or product, or this or that feature of a protecting product, it must be confessed that none of this special work created or formed the basis for the new technical science.

It is readily granted that without these specialized investigations, oftentimes brilliant and conducted in the most thorough manner, the new science could not have been started.

Pioneer Work
in the
New Science

Notable examples of such preliminary work are:—

The researches of Dr. Dudley into the use of inert material, and the absorption and permeability to water of linseed oil.

The practical tests of Harry Smith, F. I. C., on corrosion of iron in 1899.

The researches of Maximilian Toch, of Hooper,

Hughes and Thompson; the deduction and studies of men like Heckel, Scott, etc.*

The Paint Manufacturers' Association of the United States are directly the sponsors for the new technical science.

Realizing that the progressive paint manufacturer needs endorsement, by scientific law itself, of certain fundamental "rule of thumb" principles of the art, the Paint Manufacturers' Association created a Scientific Section, for the purpose of lifting the industry from the basis "of the most probable guess" to the basis of exact data, from which fact and law can be deduced.

The Founding
of the
New Science
by the
Paint
Manufacturers

In seeking data from which to deduce fundamental or primary law, one must turn, first, to nature, in the hope that by chance animate nature may have worked out similar problems.

One should also collect the data to date of the accumulated experience of mankind in relation to the work under investigation; apply the laws and experience in allied sciences, that present similar problems, and bring all into harmony with the new work; and, above all, test every generalization, every suggested theory, to find that it does not conflict with accepted law in other branches of science.

Then bring all possible tests to bear, remembering that if all variable conditions and factors be accounted for and corrected for, that no generalization can be a law that has a single exception, after such allowance for variables.

The purpose of the new science of exposed protective coatings is to give the best preservation to structural materials, which to-day means, primarily, the more de-

* "Corrosion of Iron," by Dr. A. S. Cushman. "Function of Oxygen in the Corrosion of Iron," by Dr. W. H. Walker. Harry Smith—see J. S. C. I., Vol. 18, Dec, 30, 1899. "Chemistry and Technology of Mixed Paints," by Maximilian Toch. "Electrolytic Corrosion of Structural Steel," by Maximilian Toch. "Tests of Paint," by Dr. Chas. B. Dudley. "Notes on the Structure of Paint Films," by L. S. Hughes. "The Two White Leads," by W. G. Scott. "Treatise on White Lead, Linseed Oil, Etc.," by A. H. Hooker. "Method for Protecting Iron and Steel Against Corrosion," (a Review) by G. B. Heckel, *Jour. of the Franklin Institute*, June, 1908.

structible wood and steel; and the less important, in that they are less perishable, bricks, cement, and similar materials.

**Definition
of the
New Science** The work of the new science, from the very nature of the materials, at once divides into two great departments, similar to those of organic and inorganic chemistry, namely:

The science of "protective coatings for organic structural material," notably lumber, with the peculiar problem of preserving its cellular tissues.

The science of "protective coatings for inorganic structural material."

This latter department of the new science may be divided into two groups: The oxide-forming materials, such as the metals—iron, etc.; the compound mineral materials, such as masonry, cement, bricks, etc.

CHAPTER III.

THE PROTECTIVE COATINGS OF ANIMATE NATURE.

With the purpose of the new science, and the particular materials which it is to benefit, well in mind, let us now turn to animate nature and study the protective coatings she has created.

Investigation of
Nature's
Protective
Coatings

We can at once choose the following important list: The bark or shell, or outer covering of vegetation; the shell of invertebrates and the skin of vertebrates; and, lastly, the temporary repair of partial break or loss of any of these coatings, by means of viscous organic liquids, which by oxidation form semi-solid coatings, as, for example, the gums in vegetable life, soft shells on invertebrates, and new skin in vertebrates.

It can be noted that nature has provided, through no uncertain law, the best possible coating for each of these forms of organic life, and for the most highly developed, the most perfect coating.

In vegetable life, nature furnishes a coating for the season only, or, in other cases, new coatings perennially; the normal coat needs and has neither great strength nor impenetrability, but develops cellular structure rapidly to approximate the cellular fibre of the plant.

Coatings for
Vegetation

In vegetable life, a wound is healed by a flow of sap to form a relatively thin coating, which, by oxidation, hardens into a viscous, semi-solid mass with characteristic power of internal elasticity and adjustment to strain, but rather soft, as its service is but temporary.

In the case of invertebrate life, where the safety from attack, accident or wear depends entirely upon the coating, the coating is formed from liquids, but changed to a solid, containing a high percentage of mineral constituent to impart strength and hardness.

Coatings for
Invertebrates

Coatings for Vertebrate life shows us a triumph of nature in pro-
Vertebrates tective coatings, the animal and human skin in its various forms.

This covering is produced, like the others, from the circulating liquids of the living structure, which gradually oxidize to a semi-solid mass, as nature may require.

Here we find the same excellent and sufficient power of internal adjustment and of accommodating elasticity more marked even than in the oil or gum films or coatings of vegetable life. We find the same pores or voids, it is true, because here, again, nature has planned progressive wasting and progressive rebuilding, and here, also, has direct use for the voids or pores, but with two marked requirements, and hence, two careful provisions, in this highest type of protective coatings.

Nature here declares in positive terms that where a hard surface is needed it shall be provided; and, accordingly, produces claws, nails, etc., of more solid structure and with a higher percentage of hard mineral matter. Again, nature declares that this most perfect protection she provides, the human skin, shall have three layers, or skin coats, if we include the glassy coating, all infinitely close in their interrelation, but giving wonderful adjustment to accommodate the expansion and contraction of the substructure to any sudden or slow change of form.

To summarize these observations: nature tells us that her best protective coats have been formed of a viscous organic fluid that can readily adapt itself, and which, by progressive oxidation, forms an elastic skin, capable of great internal adjustment to strain; that this skin should be three-fold, or three-ply, and that where wear is needed this coating should be hardened by mineral components.

CHAPTER IV.

ARTIFICIAL PROTECTIVE COATINGS, PREVIOUSLY CREATED BY RULE OF THUMB.

Thus nature, through ages of evolution, has succeeded in protecting cellular tissue, whether timber or skin, with highly developed fluids which form thin coatings that harden by oxidation.

Let us now turn and study what human experience, through the ages, has evolved or produced or utilized to protect after death these same materials, namely, lumber and hides. Mankind, as the result of accumulated experience, has settled upon three materials for principal use, namely, (1) tan liquor for inhibiting putrefaction of animal cellular tissue, in the shape of hides; (2) various gums or oxidized products of sap, used in the shape of varnishes for protecting woodwork, which has little or moderate exposure to agencies of decay; (3) linseed oil, or the oil of the flax seed, for use in the vehicle of the paints to protect vegetable cellular tissue in the shape of wood, from decay.

Of extreme interest to the manufacturer of protective coatings is the wonderful fact that, as a result of ages of human experience and of human groping, by rule of thumb methods, after the best results, mankind has been led to choose these vegetable oils and gums so closely paralleled to nature's own work in evolving protective coatings.

Linseed oil is a viscous, semi-fluid, which spreads in a thin layer and which, like vegetable sap, through oxidation hardens into an elastic skin or gum, which is known as linoxyn.

This linoxyn, or dried coating of linseed oil, is remarkably similar in its physical characteristics to the human

Investigation of
Past Efforts to
Produce
Artificial
Protective
Coatings

Analogy
Between
Natural and
Artificial
Coatings

skin, that most perfect result of nature's effort to produce a protective coating. An examination of linoxyn shows this same remarkable elasticity and adaptation to strain that is characteristic of the human skin. Human experience has shown also that two or three coatings of this linoxyn, like the triple layers of skin, are necessary for a thorough protective coating, evidenced in the customary two or three coats of applied paint.

Less Permanent
Coatings
Required by
Growing
Structure
Than by
Structural
Material

It is necessary, however, for human ingenuity to supply in the use of linoxyn that which animate nature supplies where necessary through the living tissue.

In the case of the coatings produced by animate nature, the tendency to perish or wear away is counteracted by a constant replenishing from the living structure back of the coating, as, for example, where new epidermis is formed as rapidly as the outer glossy layer is worn away.

Artificial
Coatings for
Structural
Material

In artificial protective coatings, such as the linoxyn film, where no natural replenishing occurs, it is necessary to ingeniously give a maximum life or endurance to the original coating.

The natural skin is porous, and these pores or voids are required by nature.

Require
Artificial Aid
to Strength and
Durability

The artificial coating has a similar porosity, but the pores or voids of the artificial coating increase its tendency to perish and must be filled up by human ingenuity.

Without any clear conception of these facts, and without any particular knowledge of this technical problem, the experience of mankind has resulted in the reinforcing of the linoxyn film with fine particles of highly resistant matter known as pigments, to lengthen its life.

The Use of
Pigments to
Increase
Durability of
Protective
Coatings

These pigments must be used to fill the pores or voids in the linoxyn, to give it a surface which will better resist abrasion, and, above all else, by filling the voids, tend to render the linoxyn more resisting to agencies of decay.

In the use of these pigments it is possible to still preserve a sufficient amount of the relative elasticity of the linoxyn and yet add the essential properties of a solid to the dried coating of paint.

CHAPTER V.

THE LAW OF MINIMUM VOIDS WITH THE USE OF PIGMENTS CONTAINING PARTICLES OF PARTICULAR OR DETERMINATE SIZES.

A careful consideration of the combination of solid material with a semi-fluid vehicle, shows that in many respects the problems are identical with the problems involved in the preparation of concrete.

Just as with concrete, the problem is to produce strength with the minimum of voids by using a mixture of particles of three or more determinate or characteristic sizes, just so, in the coating of paint, a minimum of voids and a maximum of imperviousness can be obtained by a wise selection of three proper materials which supply these three different determinate or characteristic sizes of particles. This proposition was stated as a matter of scientific deduction, by the writer, in 1906, in papers read before the American Society for Testing Materials, and also before the Detroit Chapter of the American Institute of Architects.

To-day it is possible to prove and confirm this law by a simple yet striking experiment.

We can first demonstrate that a film of dried vegetable sap or oil, such as linseed oil, which the chemist calls linoxyn, is filled with what the cement expert calls "voids" and is porous, and the following table will show the rapidity with which carbonic acid gas actually passes through such films of linoxyn with various pigments incorporated or ground into the oil. Taking the porosity of a film of oil and asbestine as 100%, we find as follows:

Asbestine	100.00%
Corroded white lead	89.10%

A high grade scientific paint, containing
white lead, asbestine, and zinc oxide ... 71.00%
on two hours' treatment.

The Analogy
of Coatings
to Concrete

The Law of
"Minimum
Voids"

Porosity of a
Coating of
Linnoxyn

Test for
Relative
Porosity of
Various Paint
Coatings

Now, let a number of films of linoxyn be prepared, the first containing, say, one pigment, such as barytes, another containing two pigments, such as barytes and blanc fixe, and a third film, carrying three pigments of different sized particles, for instance, barytes, blanc fixe and zinc oxide; let these films be used as covers or seals for as many glass receptacles.

It will be noted that the barytes has the coarse particle characteristic of a natural mineral, and that the precipitated blanc fixe has a smaller but characteristic size of particle, resulting from its precipitation from solution, while the zinc oxide has an infinitely fine size of particle, due to its formation from a fume, a particle size so fine that while passing over as a fume from the furnace to the solid form, it shows characteristics of gas tension.

Let us place in these glass receptacles, previous to sealing, a reagent or chemical which will absorb carbonic acid gas and fix it chemically in such a way that we can measure or weigh it. Ordinary lime water which can be purchased in any drug store will do this, and will form with the carbonic gas, calcium carbonate, or common whiting; or we can substitute color indicators sensitive to carbon dioxide. If these receptacles be now placed in a tight room or container filled with carbonic acid gas at somewhat above atmospheric pressure and so that the gas is pressing equally on each skin, it is evident that we can measure the relative porosity or sponginess of each film by the amount of gas which it allows to pass through from the outside into the container which it seals. Thus we obtain a comparative measure of the effectiveness of any pigment or group of pigments taken to close the pores or voids which have been mentioned as existing naturally in the linoxyn itself. The average results obtained from a number of such experiments show that beyond all question pure linoxyn without pigments is extremely porous. It is also shown that a paint must have pigments in it; that one pigment does part of the work of filling the voids; that two do more of the work; but that if three

or more pigments of different sized particles are used to make the paint, we get much better excluding values, and go a great step forward in making the paint skin sufficiently impervious to gas. Similar experiments yield similar results with regard to moisture.

It has thus been shown that it is necessary to use a fluid or vehicle for producing the coating and one which will give accommodating elasticity.

It has been further shown that it is necessary to use pigments to render the paint coating more impenetrable to gases, moisture and other agencies of decay, by the use of pigments or particles of three or more characteristic or different determinate sizes.

Many of the problems involved in the art of making paint are yet to be solved. If one valuable pigment be used as the base of the paint, its size of particle and its physical characteristics will cause the efficient manufacturer to choose those other particular pigments which will properly balance the valuable base pigment so chosen, but the exact proportions to give the minimum of void with the maximum of oil elasticity is not yet a precise science, and we must for the present be guided in this by the ripe experience of the conscientious manufacturer.

If we take paint films composed of various pigments and test them with the Perry Film Testing Apparatus, which gives an approximate measurement of the elastic limit or limit at which a paint skin, composed of linoxyn and the pigment, will break, we get data which shows that white lead or similar pigments should be largely used to preserve or rather to avoid depletion of the elasticity of the linoxyn; the experiment also shows that zinc oxide or similar material with extremely fine particles should be used in fairly liberal proportion to fill the pores, but that excessive use of a pigment of this kind will destroy the proper elasticity of the film and produce cracking and peeling.

We also find that asbestine, or similar materials with needle-like structure, used in moderate proportion, add

Minimum
Porosity
with Minimum
Voids

Elasticity from
the Linoxyn

Density from a
Mixture of
Pigments

Proper Use of
Different Sizes
of Pigments

Testing
Apparatus to
Determine
Elasticity of
Various
Coatings and
Formulas

Reinforcement
of Coating with
Asbestine

wonderfully to the strength of the paint coating. Thus the result of human experience in compounding high grade paints is confirmed by the apparatus which measures the porosity of the paint, and again by the apparatus which measures the elasticity and strength of the film.

CHAPTER VI.

PROTECTIVE COATINGS THAT EXCLUDE DECAY VS. THOSE WHICH BOTH EXCLUDE AND INHIBIT DECAY.

The past forty years measures a very great advance in the production of paints for paint coatings to exclude moisture and gases, the agencies of decay.

Efficiency of
Paints as
Excluders of
Decay Agencies

The forty years have produced some high-class paints which to-day give a minimum of pores or void spaces and a maximum of constant impenetrability and of exclusion to agencies of decay, greatly accommodating elasticity from the linoxyn, so that the paint coating accommodates itself to the expansion and contraction of the structural material upon which it is applied, in short, the art up to date has produced coatings which are very good "EXCLUDERS" or good water-proofs for the structural material to be protected.

Up to the year 1906, however, neither the paint manufacturer nor the consumer questioned much if any whether the materials used were beneficial or harmful to the structural material upon which they were applied.

Choice of
Materials for
"Excluders"
Disregarded
their Action on
Structural
Surface

Up to 1906, the manufacturer paid great attention to the problem of preventing internal chemical action or chemical change within the body of the paint coating itself, but it never seemed to have occurred to him or to the consuming public that in the excellent excluder or water-proof coating, the materials themselves would perhaps have chemical or other action upon the surface of the *structure* to be protected.

It may be of interest to compare the present situation in the science of protective coatings with the situation in medical science at the time when Pasteur fought his battle for antiseptics during the period following the

Analogy of
 Excluding
 Paints to the
 Excluding
 Bandages
 of Surgery
 Prior to Pasteur

Franco-Prussian War. At that time medical science treated wounds by cleansing the surface and bandaging. Pasteur first insisted that antiseptic treatment and antiseptic bandages must be used.

The development of protective coatings has given us excellent bandages or excluding coatings, which, like the old surgeon's bandages, have been primarily constructed with a view to *excluding* the agencies of decay.

The new discoveries and the new science do not ask that we rob our paint coating of any of the qualities of strength, durability or imperviousness which we have attained to while developing these materials as *excluders*, but, while maintaining all these values, we must eliminate any pigment which would be harmful to the surface which the paint is intended to protect, and at the same time add those materials which, without injuring any of the other qualities of the paint, will tend to inhibit decay.

Excluding
 Paints Should
 also be
 Inhibitive or
 Antiseptic

The new science has made rapid strides in the past two years in furnishing data relative to the cause of corrosion of iron and steel and of the action on iron or steel of the various materials used in the paint industry. Similar work on cellular tissue presents grave difficulties which have rendered our advance much slower.

CHAPTER VII.

THE POSSIBLE INHIBITION OF THE DECAY OF ORGANIC STRUCTURAL MATERIAL, LEATHER, LUMBER, ETC.

The broad question, whether the inhibition of the decay of organic cellular structure may possibly be subject to broad, scientific law, does not seem to have been raised.

It is extremely interesting to note that animate nature and human experience have both availed themselves of materials so nearly identical, and, more particularly, that from the life-bloods or life fluids of living structure are obtained these materials, which, although drawn from putrefiable bodies, will, none the less, arrest or inhibit putrefaction when applied to the unaltered structure of other putrefiable bodies.

The oils or fatty acid compounds thus derived from the life fluid of living cellular tissue are oxidized through alcohols and aldehydes into acids.

Is it not possible that nature has not only given an excluding coating to protect animate structural material, but actually produces, through the addition or subtraction of oxygen other compounds which tend to inhibit putrefaction or decay?

Should we not investigate to see whether this is not an open page from which we, by study, may ascertain a generic law or great generalization that among a certain class of compounds we may find inhibitors of decay? The problem has to be stated in the nature of a question because no great generalization or general assumption seems to have been heretofore made, as the basis for investigation into this very vital subject. While brilliant scientific investigation has been made along special lines in regard to isolated questions, such, for instance, as

Inhibition of
Decay in
Lumber and
Other Cellular
Growth

Have We a
Group of
Inhibitors of
Organic
Putrefaction?

Possible Value
of the
Group of
Aldehydes

the use of acetaldehyde and piperonal (heliotropin) as antiseptics and of certain problems in the use and characteristics of linseed oil, also certain problems connected with the gums, yet these materials have been almost entirely used in industries which are not yet subjected to the control of exact science.

The question should be carefully investigated and studied whether the group of compounds known as aldehydes are not perhaps nature's instruments for inhibition of putrefaction, and whether these compounds cannot be availed of by man for similar inhibition of decay, a question which carries us beyond the limits of our present problems, because it involves the manufacturing of materials such as leather and touches even the realm of medical science.

The subject cannot be dismissed, however, without drawing attention to certain striking facts, well worthy of the attention of the investigators, whether by doctors or tanning chemists, or by those who seek to inhibit lumber and timber from decay.

Tan liquors *will* inhibit the putrefaction or decay of animal tissue in the shape of hides, that is, they render gelatine insoluble.

Reactions of Tannins

But tannic acid, according to such authorities as J. T. Wood, Weiske, and Strasny, will *not* precipitate gelatine under chemically pure conditions. The leather chemists have not yet clearly demonstrated just which organic constituents of tan liquor perform this essential function, but this brings tannin into line with the tanning salts of chromium and the aldehydes, inasmuch as these latter do not precipitate gelatine from solution, but *do* render gelatine insoluble.

Action of Aldehydes on Gelatine

The aldehyde of formic acid, known as formaldehyde, will inhibit the putrefaction or decay of hides and render gelatine insoluble.

So, also, will the aldehydes of stearic and acrylic acids.

It is a problem well meriting careful research to determine whether some group of organic compounds, pro-

duced from the vital fluid of living structure by the addition or subtraction of oxygen, such, for instance, as the aldehydes, are not, perhaps, nature's great instruments to inhibit decay or the perishing of organic structure.

The next important question which the above facts suggest is whether linseed oil, which, like tan liquor, is a product from the vital circulating fluid of living structure, and which is known to be chiefly composed of a compound of linoleic acid and glycerin, whether this linseed oil itself does not yield aldehydes which inhibit the decay of vegetable fibre. The above facts are stated regarding the aldehydes, and this speculative question is raised, as to the service of aldehydes in inhibiting putrefaction or decay, in the hope that it may stimulate others to make scientific investigations along these lines, and in the hope that, even should it be found that the aldehydes are not involved in performing this service, at least by scientific investigation we may discover whether nature has not provided some such series of organic compounds for this vital function.

The above question is, of course, distinct from the question of bacteriological decay, and distinct from any possible function of the aldehydes as antiseptics.

CHAPTER VIII.

THE INHIBITION OF THE CORROSION OF STEEL AND IRON AS STRUCTURAL MATERIALS.

The direct relation of the materials used in paint, to the corrosion of steel and iron, and the extent to which they might stimulate decay, seems never to have been investigated. Also, the possibility that ingredients might be used which would act as antiseptics or inhibit the corrosion of iron and steel, seems to have occurred neither to the manufacturer nor to the public. The researches of Dr. Allerton S. Cushman, of Dr. William H. Walker, and of other scientists, equally well known, have during the past two years awakened both the manufacturer and the public to this problem, and it has been clearly demonstrated that there is an important and measurable difference between the behavior of various materials used in the paint business, and that some of them conserve while others tend to destroy the underlying structure.

Preservation of Steel and Iron

Turning, therefore, to the conservation of structural iron and steel, and to its rust inhibition through particular coatings, we have the problem of choosing the proper materials for manufacturing a paint which will both exclude the agencies of rusting, and which, when moisture and gases do penetrate the coating, will inhibit the iron from rusting; and we also have the problem of giving to the chemist, engineer and architect some simple method of determining whether any given paint is, in at least rough measure, harmful, safe or beneficial.

In the case of structural steel we have a condition of the surface to be protected, essentially different from the conditions existing with lumber.

Lumber, no matter how well kiln dried, invariably has some moisture in its structure.

It has been absolutely demonstrated, and all technical men acquainted with the subject are agreed, that linseed oil, when dried to a coat of linoxyn, has voids or pores in it.

Permeable
Nature of
Oil Film

The paint manufacturer uses a combination of pigments which largely fill these voids, but the most carefully prepared coat of paint for lumber, when the vehicle is linseed oil, without the addition of varnish, is always somewhat porous, and the moisture has some opportunity to pass out without blistering, etc.

In the case of structural steel we have no moisture in the structural material to contend with, as we have with lumber, and, therefore, we can safely add varnish gums in solution to the linseed oil, thus producing a more nearly water-proof coat to the agencies of decay.

Structural Steel
Requires a
Non-Porous
Film

The action of the gum, diffused throughout the linseed oil by solution, is to help to fill up or fuse together the pores or voids, or, in other words, to render the linoxyn film more resistant to the entrance of moisture and prevent the passage of moisture through the paint coating to the structural material.

Varnish Gums,
in Oil,
Reduce
Porosity

This is the conclusion reached from the standpoint of technical research, and practical experience has also demonstrated that those coatings which have been proved the best protection for steel, have invariably contained a vehicle in which some gum or varnish material has been present.

Anti-Rust
Paints
Improved by
Gums in
Vehicle

It is a fairly safe generalization that the vehicle should thus be so modified as to produce a more fluid and less porous coating for structural steel and iron, while at the same time the paint must be most carefully compounded, so far as the solid pigments are concerned, to give a minimum of voids and a maximum of strength and of durability.

If the conditions which give physical strength and durability have been observed, the one other precaution which is necessary is to avoid the use of any pigment

Necessity for a
Blend of
Pigments to
Fill Voids

Caution
Regarding
Pigments
Chemically
Active with
Oil

which would be chemically active, either with regard to the vehicle or with regard to the structural steel and iron.

A number of the pigments which are used in the paint industry, unfortunately, react with the linseed oil and tend to produce internal disintegration of the coat, as, for instance, white lead.

Other pigments largely used in the paint industry, and of value in a paint for protecting lumber, are unjustifiable in a paint for the protection of steel and iron.

Caution
Regarding
Pigments that
Corrode Steel

For example, sulphate of calcium, which, even if fully hydrated, has been shown to have a direct stimulative action upon steel.

This is due to the fact that calcium sulphate, even if fully hydrated, is somewhat soluble in water, and when the water penetrates the coating of paint it carries this calcium sulphate into solution.

Caution
Regarding
Calcium
Sulphate

Due to the fact that calcium sulphate, in solution, has a high co-efficient of dissociation (or, in other words, has a tendency, in solution, to break up from its chemical form and identity), we get the reaction of the liberated sulphuric acid ions upon iron and steel, causing corrosion.

The highest type of paint products for the protection of iron and steel, therefore, avoid the use of such pigments as calcium sulphate.

Great caution must be used in selecting iron oxides for the protection of iron and steel, as they often carry traces of sulphates, etc., as impurities.

Caution
Regarding
Venetian
Red

Venetian red, which is a favorite pigment, and which is of value for protecting lumber, is made by calcining green vitriol or sulphate of iron (commonly called cop-peras) in the ferrous form, in the presence of quick lime. The resulting mass from the furnace consists of artificial oxide of iron and sulphate of calcium, produced by the metathesis of the above reacting compounds.

Unfortunately, the reaction is never complete, and there is a tendency towards the formation of free sulphuric acid.

As a result, we have all the bad effects with Venetian

red that we find in the use of calcium sulphate, and also the extra chance of corrosion due to free and aggressive sulphuric acid present.

It is true that there are some *artificial* oxides of iron which can with safety be used, as, for instance, artificial black magnetic oxide produced by chemical precipitation, but, as a general proposition, the *natural* iron oxides should be used, unless it is absolutely certain that the artificial oxide has been proven safe.

Ochres are not meant to be included in the safe class in the above statements, for the reason that ochre is an extremely impure oxide of iron.

Recent investigations into the nature of pigments have revealed the fact that they may be divided into three groups and termed Rust-Inhibitives, Inerts or Rust-Stimulators. The nature of the pigment itself, or the nature of the impurities contained within the pigment, are factors deciding the position of the pigment in one of the three groups or types above mentioned. It may be expected that the use of rust-inhibitive pigments in paints designed for the protection of steel surfaces will give to such a paint very valuable properties. Further consideration of the subject will aid us in selecting the proper pigments for such a purpose.

According to the electrolytic theory of corrosion, certain fundamental principles underlie the corrosion of iron.

They are, briefly, as follows:

That, when iron is in contact with water, there will be a transfer of electricity from the free hydrogen ions of the water to the iron ions of the iron, causing the solution and subsequent oxidation of the metal.

We are indebted to Dr. William H. Walker for the most recent research on the function of oxygen in the corrosion of iron:

"That the film of hydrogen thus deposited on the metallic iron at the beginning of the action is a non-conductor of electricity and prevents further passage of the current, and hence, further solution of the iron. At-

Caution
Regarding
Artificial
Oxides of Iron

Ochres

Grouping of
Pigments into
Inhibitors
Inerts
Stimulators

Electrolytic
Theory of
Corrosion

atmospheric oxygen removes the film of hydrogen by combining with it, thus 'depolarizing' the iron and allowing the solution of the iron to proceed. When once in solution in water, this dissolved iron is also oxidized by the atmospheric oxygen and precipitated as rust; but this oxidation is incidental to, rather than a necessary condition of, corrosion.

"That when iron is in contact with any surface on which this combination of the hydrogen, set free from the water, and oxygen, from the air, will take place more easily than on the iron itself, such as copper, bronze, mill-scale, etc., corrosion of the iron will be accelerated thereby."

The presence of impurities having a difference in potential to that of the iron in which they are contained, and the uneven distribution of such impurities, increases the amount of electrical action.

Certain compounds are of such a nature as to excite electrical action, and, consequently, stimulate corrosion, while still other compounds are of such a nature as to inhibit or prevent corrosion.

To the class of compounds that inhibit corrosion belong bi-chromates of the alkaline earth metals, these salts being pre-eminent among such compounds. It has been found that salts of certain metals may be precipitated with the chrome salts to produce pigments which afford protection for the steel surfaces to which they are applied.

Value of
Chromate
Pigments
as Rust
Inhibitors

The results of a series of investigations into the rust preventive nature of these compounds demonstrated that it was not safe to state that the chromates, as a class, were rust-inhibitives. Quite the reverse is true of many of these products and their composition, method of preparation, and impurities are factors which influence, to a marked degree, their value as protective compounds. Aside from those chromates which prevent corrosion, we have those which act in an inert manner, also those in which any inhibitive value is overbalanced by the effect

of impurities, showing a strong stimulating action in the rusting of metal. But a simple test will show in which class the chromates come.

CHAPTER IX.

THE STEEL TEST FENCES TO CONFIRM SCIENTIFIC INVESTIGATION OF RUST INHIBITIVES.

Steel In order to ascertain the rust-inhibitive value of all
Test Fence pigments, the Scientific Section was commissioned by the Bureau of Promotion and Development of the Paint Manufacturers' Association to erect a fence, having several hundred steel plates, upon which to try out the value of the different pigments when contained in an oil medium.

The American Society for Testing Materials was informed of the work proposed by the Scientific Section, and Committees E and U of the society decided to cooperate in inspecting and supervising the tests, proper specifications to be drawn up by these committees. The members of these committees and the Scientific Section conducted laboratory tests that served as a check upon the previous investigations and gave information upon which to base the main field tests. The plates used for the tests were rolled from three kinds of metal—ordinary open-hearth structural steel, ordinary Bessemer low carbon steel, and pure ingot iron. In this way we will secure data relating to the resistance to corrosion of certain metals when tested out simultaneously with others. The steel plates were painted in two ways, part of them being scratch-brushed in the ordinary way before painting, thus following out the usual mode of painting structural steel, and part of the plates being pickled in sulphuric acid, in order to completely remove the scale, and the plates were subsequently washed with lime, so that all traces of the acid were neutralized.

The test was conducted in a thoroughly systematic and practical manner, following out the methods employed

during the tests already made at Atlantic City and Pittsburg. The Master Painters' Association co-operated with us in the work and gave us the benefit of their practical experience in this line. Inspectors and painters, representing the committees and sections, were upon the ground throughout the work.

CHAPTER X.

THE SWEAT-BOX OR ACCELERATED FIELD TEST FOR DETERMINING VALUE OF STEEL PAINTS.

Very few corporations, whether manufacturing paints or buying paints, and very few engineers or architects have the facilities or the time to make exhaustive laboratory research when choice is to be made of a protective coating for their use.

Accelerated Steel Rusting Field Test for Office

It is necessary to give the practical and busy man who needs some guidance on this question a simple and sure measure, even though the measure be only a fair approximation of the behavior of one paint as against another, and of any one material for a paint as against any other material, and all with reference to the results upon steel and iron. The method of testing by Harry Smith, in 1899, is not adapted for this purpose.

With this end in view, the following test is suggested:

The idea of this test is to duplicate as exactly as possible, on the most convenient and smallest practical scale, the conditions under which the steel has to perform actual service over a term of years, and to obtain, in a few hours, results on various materials, which results, by comparison amongst themselves, will give a fair indication of the results which will show on structural steel over a term of years when protected with these various materials.

This accelerated field test consists in subjecting strips of any particular kind of steel that may be chosen to an atmosphere of maximum humidity, the steel being in intimate contact with the materials concerning which results are desired.

What the practical man—either the paint manufacturer, the architect, or engineer—requires, is to have some prac-

tical result, easily obtainable, which will give him, in a definite and visible manner, a criterion and measure of the value of the new discovery, and of the refined laboratory work.

The apparatus is extremely simple, and the test can be started at thirty minutes' notice by any manufacturer, architect or engineer, at his office desk, and can yield him visible results in two days thereafter. Before giving the detail of how to run this test, acknowledgments should be made to Dr. Cushman for outlining the manner in which the writer might work out this apparatus.

Dr. Cushman made the first practical accelerated field test, and his method is as follows: He took a polished sheet of steel and painted sections of it with the various materials ground in water, and then placed them under wet blotting paper for forty-eight hours, after which he washed the plate, and the steel then showed in the amount of rusting which had occurred the characteristic behavior of each one of the materials in regard to the rusting of steel.

The idea was original with Dr. Cushman, and it is to him we will owe whatever practical apparatus may be evolved along these lines.

Permission was requested from Dr. Cushman to work it up in some practical way for the manufacturers of the raw materials and of paints, and for the consumers who have the work of protecting structural steel.

The materials required are as follows:

An ordinary deep cigar box.

2 or 3 sheets druggists' thick filter paper.

1 dozen thumb tacks.

1 dozen safety razor blades (unless some special steel is to be tested).

½ dozen small butter dishes or saucers.

Each of the dry materials to be tested.

A clean pencil for stirring.

A pocket knife.

A glass of water

Origin of Test

Materials
Necessary for
Sweat Box

An old towel or rag for cleansing hands, pencil, etc.

A piece of emery cloth.

A tooth brush.

2 or 3 test tubes.

The chemist, engineer or architect who wishes to conduct this test on actual paint products instead of the materials used in the manufacture of paint products, may proceed as follows:

Recovery of
Pigments
from
Liquid Paints

In addition to the list of materials given, add a \$5.00 centrifuge apparatus made by Bausch & Lomb, in other words, a small laboratory centrifugal machine holding test tubes.

Number the test tubes for reference purposes and place in each test tube a small sample of the paint to be tested, together with a large quantity of benzene.

Actuate the apparatus and most of the vehicle will be thrown away from the pigment and the pigment will settle toward the bottom of the tube.

Decant or pour off the oil, add more benzene, thoroughly shake and pour off the liquid. Do this two or three times until the oil has entirely left the paint and nothing remains but the dry, clean pigments.

Then take the pigments and proceed with the whole test as described below for the testing of dry pigments.

Sweat Box
for Testing
Pigments
on Steel

Line all six interior surfaces of the cigar box with the filter paper, using the thumb tacks for the purpose. Thoroughly wet the lining of the cigar box with water and stand it on one edge so that when it is ready for use it will be free from drip.

Place upon a piece of filter paper, large enough to cover the hand, some of the material under examination, add a few drops of water and rub up with the finger into a rather soft paste, this being easily accomplished with nearly all pigments, and bringing into a paste many pigments which are otherwise extremely difficult to incorporate with water. Be particular to cut the surface of the razor blade to the raw steel with 00 emery paper, to insure the removal of any lacquer or surface treatment of

the blade. It is necessary to handle the razor blades by the edges so as not to get any finger marks upon the surface. Now place a cleaned razor blade upon the plate, fold over the filter paper on each side of the razor blade in such a manner as to completely cover it with paste-coated filter paper, and place blade, paste and paper upon a butter dish within the cigar box.

Dr. Cushman prefers to use ordinary kitchen knives which may be obtained at any hardware store at \$1.00 a dozen.

Treat each sample of material under test in the same manner.

In the case of materials soluble in linseed oil, such as resins and linoleates, these are to be dissolved to a heavy solution in benzol, and a coating poured upon the razor blade. The evaporation of the benzol leaves upon the surface of the blade a thin film of the material to be tested, and, because of the fluidity of the benzol and consequent thinness of the film, a second coating is advisable. The coated blade is then to be placed in a butter dish within the box along with the other materials with which it is to be compared. Care should be taken that the plate is completely coated as there is a tendency for the liquid to segregate on the steel.

A word of caution is necessary regarding the testing of the inhibitives such as the chrome soaps, that are soluble in linseed oil.

These are not pigments, but soluble in the oil and vehicle constituents and therefore must not be applied in a water paste, but in a film, through the agency of benzol as above described.

If a strip of steel in every case be treated with potassium bichromate in such a test, a convenient standard of minimum corrosion will be afforded, for purposes of comparison.

If so desired, in the foregoing test the operator may increase the quickness with which the test may be performed, by adding to a little bicarbonate of soda (baking

Caution
Regarding
the Testing of
Vehicle
Soluble
Pigments

Standard
Test

soda) on a butter dish, a little sulphuric acid. An evolution of carbonic acid gas will ensue and as this gas rapidly stimulates corrosion, its presence will render the test still more positive.

Quantitative
Test
with
Sweat Box

A considerable degree of refinement and a fair index of result can be obtained from this apparatus if the strips are first carefully weighed in a laboratory balance, and then reweighed after the steel is scrubbed with a tooth or nail brush to remove any rust formed, in which case the loss in weight of the steel is the measure of the rust formed and the degree to which the pigment has stimulated rust.

It is evident to any man who will compare the conditions in this test with the field conditions, that practically all of the important factors which contribute to the corrosion of steel are present in this test in such a way that they will indicate in a short time the results which would be obtained from the steel painted with a paint coating produced from these materials and over a considerable length of time.

Inhibitive
Pigments
Necessary
in Paint Films

When we consider that the dried linseed oil or coating of linoxyn is permeable to water, and that, with successive changes in the weather, in an outside field test, we have produced conditions where the steel is exposed to air saturated with moisture (both of which have penetrated the linoxyn), and when we further consider that this moisture, which has penetrated the linoxyn, may carry to the surface of the steel the materials from the paint film, we thus see that in the open air field tests extending over a long period of time we have many different periods during which the steel is exposed to moisture carrying the materials of paint, either physically or in solution, and, therefore, in this accelerated field test apparatus the steel is throughout the test, from beginning to end, thus exposed to excessive humidity and in physical contact with the material concerning which we need information.

We have thus in the apparatus the material moistened

with water in intimate contact with the surface of the steel, and the difference between this accelerated field test apparatus and an actual field test is the continued humidity and the immediate and positive treatment of the surface of the steel with the material in question.

In this apparatus it is planned to entirely dispense with the delicate manipulations of the chemist with his determination of the power of these various materials (when conveyed from the paint films to the surface of the steel) to act as electrolytes. We also leave to one side the aid of physical chemistry to determine the dissociation of these various materials in solution, which indicates to the chemist their power to retard, arrest, or stimulate corrosion, and we leave to one side the aid of the electrical laboratory to determine whether these materials are electro-positive or electro-negative to steel, and we avoid in this test the necessary skill of the chemist and the aid of the laboratory in making refined tests on the corrosion of steel in the presence of these materials in laboratory apparatus.

The Sweat Box
Test for Use of
Engineer and
Architect

CHAPTER XI.

THE WOODEN TEST FENCES TO CONFIRM THE FOLLOWING:

THE LAW THAT A SCIENTIFIC BLEND OF GOOD BASE PIGMENTS IS SUPERIOR TO ANY ONE OF THE SAME BASE PIGMENTS.

THE LAW OF MINIMUM VOIDS FROM A BLEND OF PIGMENT PARTICLES OF DIFFERENT DIMENSIONS.

THE TECHNICAL KNOWLEDGE THAT MODERATE USE OF REINFORCING PIGMENTS ADDED TO THE BASE PIGMENTS WILL STRENGTHEN AND ADD DURABILITY TO A COATING OF PAINT.

Wooden Test Fences

A series of tests of paints on wooden surfaces were started at the suggestion of the manufacturers at their second annual meeting, in October, 1907. Prof. Ladd, of the North Dakota Agricultural College, the originator of the much-talked-of paint law in that State, started a test fence with the co-operation of the Paint Manufacturers' Association, to determine, among other things, the very important question, namely, whether two or more pigments in combination in a paint were superior to one single pigment; not, of course, any two or more pigments, good or bad, or any one single pigment, good or bad, but whether two or more good pigments, properly balanced and mixed, were superior to any one of the two or three where used alone.

Climatic Conditions

The climate of North Dakota, however, being particularly free from moisture and dampness, would naturally allow a paint longer life than in many other parts of the country. Furthermore, the remoteness of North Dakota from the more densely populated centers of this great nation, and the distance which many must travel to reach this fence, has precluded the possibility of frequent inspection by the practical master painters and by

other authorities on the subject of paint, and it is to these gentlemen that we are to look for the final verdict of our tests.

For the reasons cited, it was deemed necessary to have similar tests started in other parts of the United States, where more severe climatic conditions are prevalent.

Atlantic City at once suggested itself, as being a place in which the destructive elements would afford an accelerated test. The American Society for Testing Materials, a body of high scientific repute, chose a committee, composed largely of government scientists, to supervise and inspect the Atlantic City fence, and they have worked in close touch with the Scientific Section and the Philadelphia branch of the Master Painters' Association of Pennsylvania. This latter body chose Mr. George Butler, of Philadelphia, as the official painter of the fence, and his men were present during the entire period. Thus it is clear to see that absolutely unbiased treatment was given every compound applied.

Atlantic City
Fence

Pittsburg was selected as a suitable location for another fence, because of the variability of its climate, its smoke-laden air, and the general conditions which prevail in that city, which would tend to cause rapid destruction of paint. At Pittsburg, the local branch of the Master Painters' Association appointed Mr. A. C. Rapp, the president of that association, as the official painter of the fence, and his men were present throughout the work, together with the inspectors and chemists of the Scientific Section and the inspectors appointed by the Fence Committee of the Carnegie Technical Schools, who accepted supervision and inspection of the fence. This latter body is composed of professors of the Faculty, who are men of widely acknowledged scientific reputation, and the whole school body has been interested in the tests.

Pittsburg
Fence

Thus, because of the excellent opportunities for rigid control by unprejudiced committees, and because of the opportunity for frequent inspections which these fences

afford, and because of the accelerated action which these climates will give, we could have no better places for such tests.

It has been the endeavor in these tests to cover every practical point possible. Instead of painting out each formula on one panel, each test has been made in duplicate on three kinds of wood, thus allowing each formula six sections of panel, half of which are exposed on one side of the fence, and the other half on the reverse side.

Excessive Use
of Inert and
Reinforcing
Pigments to be
Determined by
Test Fences

A series of formulas, containing varying percentages of inert pigments combined with the typical white base pigments, were also tried out on the association fences. These paints were designed to show safe limits within which the manufacturer could use these inert pigments in order to benefit and render better for use the paints he is producing. A number of white leads, largely used by the master painters of the country, were also tried out upon the fence. These, together with a number of formulas of new types, made up the balance of the tests.

Value of
Reinforcing
Pigments in
Test Fences

The percentage of the reinforcing pigments, such as silica, blanc fixe, silicates, whiting, etc., which were used in certain of the formulas, will prove a measure of their value when used in small amounts. These pigments have their own marked qualities and defects, but when used with precision, moderation and understanding, their addition to paints lends valuable properties.

General Scope
of Test Fences

The scope of the work which we have started on steel and wooden fences at once appeals to all interested in the preservation of these two great classes of building materials—to the architect, the engineer, the technical man, and even to the layman. When we stop to consider the varied uses to which proper protective coatings may be put, and the importance of conserving the structural material, which we now use in such immense quantity, from decay, we cannot put too much emphasis on the value of all such work.

SUMMARY.

The inhibition of wood from decay by the possible use of aldehydes, and further research on this subject, are of extreme importance. The rust inhibition of steel and iron is necessary at once; and in closing I will ask you gentlemen to turn these matters over in your minds, and render all possible aid to the solution of these problems.

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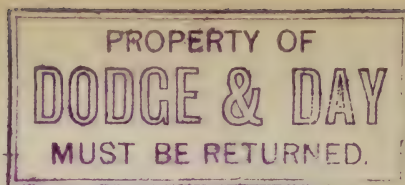
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- 14—Coatings for the Conservation of Structural Material. (In press.)

Bulletin No. 11



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THE CORROSION OF IRON AND STEEL

BY ALFRED SANG

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President James K. Lyons

In the Chair

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THE CORROSION OF IRON AND STEEL

By Alfred Sang

THE DECAY OF IRON

The decay of iron and steel by corrosion, if natural agencies are allowed to act on them, is far more rapid than that of wood and other materials of construction. Steel is being used more and more every day for buildings and other permanent structures and therefore on the prevention of this decay depend the permanency of these works and the safety of future generations. Were it not for iron and steel, the erection of large works of engineering would be impossible and their very size and consequent high cost, representing as it does a large sum of human energy—which is after all the only true foundation for wealth—make it a duty to preserve them from decay.

On a structure like the Forth bridge, a number of men are kept at work, cleaning rust-spots and repainting. The wise course of preserving such structures for the use of our descendants is not generally followed, and it is only when accidents like the one at Charing Cross Station in London

take place, that interest is revived, for a time, in the question. Wood, in referring to the roof of a gas-works in New York City which collapsed for lack of attention, forecasted a similar fate sooner or later, for structures like the viaducts of the elevated railway of the same city, which almost casual observation will show are repainted *over* the rust without cleaning.

On account of this necessity of combating corrosion, it is imperative that engineers arrange the design so that every part of structural works be readily accessible for frequent inspection. It has been truly said that "wrought iron is not only a bad but a dangerous material if neglected"; this is equally true of steel.

COMPOSITION OF RUST

In order to bring about improvements in the protection of metals from corrosion, it is necessary to study the nature of this corrosion; to devise either preventives or cures the disease itself must be understood.

Rust is a hydrated ferrous sesquioxide ($\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$) of a brown, red-brown or yellow-brown color; when formed under water it is generally of a deeper tint and is of a somewhat colloidal nature. Rust formed under water in the presence of a small amount of acid, is partly colloidal or embedded in a colloidal matrix of uncertain composition; if the rusting is intensified by applying an electric current, the gelatinous nature of the deposit becomes evident; when formed slowly, it adheres very tenaciously in the unevennesses of the surface. Its composition varies within narrow limits; according to Toch, the rust nearest the iron is highly ferrous, blending outwardly into a more stable oxide; this is due to the progressive nature of the decomposition taking place; Andrews has shown that the *rate* of decomposition also increases progressively, being, under the conditions of his experiments, about 50 per cent more rapid the second year than the first. The inner portions of a coating of rust may also contain some ferrous carbonate.

Rust is not crystalline; it is granular and amorphous;

very ancient rust is, however, said to consist of a mixture of magnetic oxide and anhydrous sesquioxide in a more or less crystallized condition, not unlike the crystalline hematite, or oligistic iron, abundant in Elba, but also found in other iron-ore regions. It is also claimed that ammonia may be formed during rusting, as in the case of organic matter undergoing decomposition; Bloxam claims that ammonia is formed from the nitrogen of the air during the process of rusting.

FORMATION OF RUST

Under normal conditions, corrosion never seems to take place evenly; upon closer investigation it is found that it does not and cannot take place evenly; this is due to "pitting"; the rust commences to form at distinct points which must therefore be particularly liable to attack. The spreading of the rust from these original points is like that of a disease. There is a peculiar formation known as "tubercular corrosion" which owes its name to the wart-like concretions of rust and earthy matter derived from the water, which grow on the metal; this form of corrosion is specially frequent in cases where alkalies and saline matter are present together in a highly aerated water; it is common in water-mains. Rusting starts at certain points and spreads out until the different growths unite into a continuous covering. The theory of pitting, due to John, is that at the point where it takes place there is a speck of impurity, such as a particle of slag or scale, or a segregated constituent of the metal, which gives rise to galvanic action.

Corrosion by pitting may reach thru a plate long before the greater part of the surrounding surface is seriously rusted. Were corrosion to take place evenly, the life of the material would be greatly extended. In proof of this Mallet made a series of experiments ⁽¹⁾; they were carried out on large surfaces and at ordinary temperatures over a long period of time; he found the following average relative depths of corrosion

(1) Trans. Inst. Nav. Arch. vol. XIII (1872), pp. 114, 115 and 116.

for one century of time for steel and wrought iron taken together:

In the atmosphere and freely exposed to the weather.....	0.0343	of an inch
In fresh river water.....	0.0352	" "
In clear open sea-water.....	0.3263	" "
In sewage-fouled sea-water.....	0.5327	" "

The tables of actual results with various grades of iron and steel which yielded the above averages are very instructive, altho the chemical compositions and physical conditions must in many, if not all, cases have differed from those of equivalent qualities manufactured nowadays.

Rust forms in layers which can be detached from each other and as it is more or less spongy, it will retain moisture in close proximity to the iron, besides giving rise to an unfavorable voltaic action. It also acts as a carrier for oxygen, furnishing it to the iron and replacing it from the air. These properties promote the growth of rust both laterally and in depth.

Rusting is the reversal of the process of iron smelting; the corrosion of iron to the sesquioxide must release the same number of calories as would be absorbed in converting a natural sesquioxide into iron.

As will be seen, while there is considerable doubt as to the necessity of an acid being present to cause rusting, there is no doubt whatever about its being essential that both oxygen and water be present; it is also claimed by some that the moisture must be able to *condense* on the surface of the metal. There are three theories of rusting and in examining them it is well to bear in mind that while one or other of them may explain the true *first cause* of rusting, the others may, and some of them undoubtedly do, present conditions which, if not essential, at least intensify the decomposition. A summary of theories has been published by Mugdan (²).

(2) Zts. f. Elektroch. vol. 9 (1903), p. 442.

CARBONIC ACID THEORY

The oldest of the plausible theories of corrosion, whose chief supporters have been Dr. F. Crace Calvert ⁽³⁾ and Gerald Moody ⁽⁴⁾, supposes that carbonic acid attacks the iron, converting it into a carbonate and releasing hydrogen which unites with the oxygen present, as air or otherwise, to decompose the ferrous carbonate to ferrous hydroxide, or rust, leaving the same amount of acid as was originally present to react as before and form more rust. The theory is a perfectly logical one. The objection that it is not proved that iron will rust in thoroly boiled distilled water is not insuperable. Stephane Leduc has shown that it is impossible to extract all of the dissolved gases from distilled water by boiling; he claims that not less than one cubic centimeter of gas would be left in one liter of water, which it is impossible to remove. Part of this gas must, almost certainly, be carbonic dioxide, of which there is 0.04 per cent present in the atmosphere; it is more soluble in water than the oxygen and nitrogen of the air.

The operation of rusting being, according to this theory, a cyclical or regenerative one, it has been argued ⁽⁵⁾ that a single molecule of carbonic dioxide would be sufficient to start and maintain corrosion in the presence of air and water. The carbonic acid, due to the combination of the carbonic dioxide with water, would, by its action, put iron into solution; this is all that is necessary to corrosion, the dissociated iron being oxidized to rust in the presence of oxygen. If, however, this residual gas in water cannot be removed by physical means, such as boiling, it may be feasible to do so chemically; even then it is possible that a definite degree of concentration of the acid neutralizer would have to exist; this would explain the rusting of iron in weak alkaline solutions.

(3) Mem. Litt. Phil. Soc. Manchester, vol. 5 (1871), p. 104; also Chem. News, Mar. 3, 1871.

(4) Proc. Chem. Soc., vol. 22 (1906), p. 101.

(5) J. N. Friend: Nature, May 14, 1908.

Dr. Allerton S. Cushman's careful experiments ⁽⁶⁾ seem to show, almost conclusively, that rusting will take place when there is no carbonic acid present; when there is, there is a greenish carbonate formed which promptly changes to the hydroxide when oxygen is supplied to it. On the other hand, while the carbonic acid theory may accurately describe how rusting does actually take place under normal conditions, and be, therefore, correct, there seems to be little reason to doubt but that rusting can take place without its aid. This conclusion, based on the valuable work of Dr. Cushman, agrees with what Mallet wrote in 1872: "If the air contains vapour of water, however, chemical action rapidly occurs, more rapidly if carbonic acid also be present. The presence of the latter is, however, not necessary to initiate the action, as has been stated by Calvert."

HYDROGEN PEROXIDE THEORY

The second theory of rusting, originally due to Traube ⁽⁷⁾, is known as the peroxide theory. According to this theory, the iron, oxygen and water are supposed to react to form ferric oxide (Fe_2O_3) and hydrogen peroxide (H_2O_2), which then unite to form the ferrous hydroxide, leaving an excess of hydrogen peroxide which attacks a new quantity of iron.

It has been found impossible to detect the presence of hydrogen peroxide during rusting, and while this failure may not condemn the theory, it makes it appear improbable. Furthermore, both Moody and Cushman claim that iron does not rust in pure neutral hydrogen peroxide.

ELECTROLYTIC THEORY

The third and most widely accepted theory is the electrolytic one. When two substances of different polarity are immersed in a suitable electrolyte—or medium containing free ions of matter—an electric current is set up and the substance from which the current flows tends to dissolve. So far as corrosion is concerned, the theory implies the solution of the

(6) Bull. No. 30, U. S. Bur. Agric., July 23, 1907.

(7) Deuts. Chem. Gesell., vol. 18 (1881).

iron in water or moisture as ferrous ions; the iron, while in this dissociated condition, is oxidized by any free oxygen present. To quote Dr. Cushman (8): "If, therefore, we immerse a strip of iron in a solution *containing hydrogen ions* (9) iron will go into solution, and hydrogen will pass from the electrically charged or ionic to the atomic or gaseous condition. In such a system the solution of the iron and, therefore, its subsequent oxidation, must be accompanied by a 'precipitation' or setting free of hydrogen. It is very well known that solutions of ferrous salts as well as freshly precipitated ferrous hydroxide are rapidly oxidized by the free oxygen of the air to the ferric condition, so that if the electrolytic theory can account for the original solution of the iron the explanation of rusting becomes an exceedingly simple one."

It is erroneous to say that iron only corrodes *when anode*. Ordinary iron corrodes whatever the galvanic position of the mass may be in reference to its surroundings; as will appear later, all that is necessary besides the electrolyte to cause corrosion, is a few voltaic couples embedded in the mass or else free dissociated hydrogen. Iron as cathode is less liable to corrosion, and this fact is taken advantage of in engineering work, to inhibit rusting.

The electrical inoxidation process of de Meritens (10), is a reproduction on a large and rapid scale of the process of electrolytic corrosion. Iron containing occluded, and therefore dissociated, hydrogen, and immersed in warm distilled water, is rusted by connecting it to the positive pole of a battery supplying a current of very low voltage; if the current is as weak as can be made to pass thru the water, the formation is one of black oxide, or the rust is converted into black oxide. If the iron is free from hydrogen it is necessary to first connect it to the negative pole so that it may absorb some. The part played by hydrogen in this process is very interesting

(8) Cushman, Loc. Cit., p. 15.

(9) Italics not in original.

(10) Bull. Soc. Intle. Electr., vol. 3 (1881), No. 29, p. 230.

and bears out the statement of Dr. Cushman which has been quoted. The dissociated hydrogen is not merely a by-product in the process of rusting, it seems to play an essential part in "setting-off" the reaction by creating a galvanic current. Free hydrogen ions are known to be extremely active catalytic agents; we will return to this subject later.

That the operation of rusting is of an electrolytic nature was very beautifully shown in the experiments suggested by Professor W. H. Walker and carried out by him in collaboration with Dr. Cushman (11). A "feroxyl" reagent was prepared by neutralizing a hot solution of gelatine with 1/100 normal potassium hydroxide, using phenolphthalein as indicator, after which a few drops of a dilute solution of potassium ferricyanide were added. The pieces to be tested were immersed in this preparation which solidified on cooling, encasing them; diffusion being retarded by the colloidal nature of the medium, local discolorations were expected to indicate the progress of chemical action. In these experiments the development of hydroxyl (HO) ions at the negative poles was shown by a pink coloration due to organic anions from the phenolphthalein, and at the positive poles the solution of the iron was shown by the blue coloration due to the ferrous cations.

In these tests it was found that, as a rule, the ends of the test-pieces were positive, giving rise to a blue coloration indicating ferrous ions, and rust was formed; at the central part where the pink coloration developed, the iron remained bright. The photographs published by the experimenters show nails which have their positive poles situated at the head and in most cases at the point also; this suggests that the compression of the head by upsetting and the squeezing of the end between the cut-off dies when the point is formed, resulting in an overstrained (crystallized) condition of these parts, may account for their positive polarity. After a while there would take place a complete reversal, the positive and

(11) Cushman: Loc. Cit., p. 3.

negative poles changing places until a further reversal brought back the original conditions, and so on continuously; in this way the different parts of the test-pieces rusted alternately.

The change of polarity is no doubt due to the formation of rust which would in time change the potential of the positive nodes in relation to the negative nodes. That after the first reversal a balanced system is not reached when there is an even coating—as far as the eye can judge—all over the pieces, might be due to an effect of persistence, similar to hysteresis, which would carry the action over the neutral point, as a fly-wheel carries an engine over the dead-center, but is more likely due to the very fact that rusting starting at separate points, there can be no really even coating as far as depth is concerned. Iron never becomes passive thru rusting.

Dr. Cushman gives a fine discussion of the relation of this electrolytic theory to the rusting of iron ⁽¹²⁾. He shows that if a piece of iron or steel is immersed in water, positive and negative spots are established; iron passes into solution at the positive spots and is converted into hydroxide, part of which piles up around those spots in crater-like formations, the rest migrating to the negative spots where it collects in the form of cones. Microscopical examination readily proves this to be the case; it is undoubtedly the correct description of "pitting" which, whether on a small or large scale, always initiates the process of rusting. Rust cannot take place unless negative and positive spots are established, the latter rusting first and continuing to do so until their polarity has changed. Hence, homogeneity is the best insurance against corrosion. A speck of impurity will give rise to a positive annulus if it is negative to the iron surrounding it. In 1822, Stodart and Faraday showed ⁽¹³⁾ that voltaic couples being present throughout the mass of commercial metals are the cause of these impure metals being dissolved more rapidly by acids than those which are of purer composition.

(12) Cushman: Loc. Cit., p. 27.

(13) Phil. Trans. Yr. 1822, p. 253.

THE SOLUTION OF IRON IN WATER

The actual solution of iron by water, whether brought about directly by the voltaic effect of the contact between the metal and its impurities, indirectly by the hydrogen ions set free by that voltaic action and giving rise to further voltaic action with the iron, or by any other causes, is the crucial point of the electrolytic theory of corrosion. Whitney seemed to have proved beyond a doubt that iron is soluble in water (¹⁴), and yet Dunstan and others failed to obtain any solution whatever under apparently identical conditions; they therefore rejected the theories that hydrogen is evolved during rusting and that iron dissolves in *pure* water. Dr. W. H. Walker supported Whitney's theory of the solution of iron as positive ions; under the same conditions, in distilled water, it is asserted that lead also will go into solution (¹⁵). To help solve the problem, Dr. Cushman devised a simple method (¹⁶) for testing iron and steel samples in water free from air and carbonic acid. In every case the metal remained bright, but rusted as soon as air was admitted. To find out if iron did actually go into solution before the admission of the gases, a small amount of phenolphthalein was added; sooner or later it showed the presence of iron by its pink color. The smallest amount of iron which could be detected in this way would be .0004 gram, and it was claimed that the indicator, altho itself a weak acid, could not account for the solution of the iron. If uniform confirmations of these results are forthcoming from equally reliable sources, the electrolytic theory of corrosion is proven, at least for *ordinary* iron, because in all these tests, while taking into account the composition of the medium, the experimenters apparently fail to take into account the minute variations which must have existed between the various so-called pure irons used. It may well be doubted if theoretically pure iron would dissolve in theoretically pure water, in which case the solution of iron, as observed by Cush-

(14) JI. Am. Chem. Soc., vol. 25 (1903), p. 10.

(15) F. Clowes: Nature, 1908, p. 560.

(16) Cushman: Loc. Cit., p. 17.

man, would be due to the galvanic action between the iron and its impurities, causing electrolysis of the water, the hydrogen liberated then forming a couple with the iron, the latter being the positive and soluble partner. Dunstan and others may have experimented with an iron of greater purity than that used by Cushman.

Dr. Cushman further explains Dunstan's failure to confirm Whitney's results, by arguing that by his method of operation he could not have had more than 0.000001 gram of iron in solution, and this would be too small a quantity to detect by means of the phenolphthalein indicator, and yet, would be sufficient to induce corrosion. He concludes that the rusting of iron is primarily due, not to attack by oxygen, but by *hydrogen* ions, in fact, as will be shown later, oxygen may, under certain conditions, inhibit corrosion.

The cause of iron going into solution remains to be found, but consideration of the influence on corrosion of the many impurities present in iron and steel may, as just stated, lead to the correct solution. The subject will be treated in a separate section, but the author's opinion may here be stated that the process of rusting, under the most favorable conditions, is as follows: Voltaic action between the iron and its impurities, or among the impurities themselves, causes hydrolysis, or electrolytic decomposition of the water. If the impurities are negative to the iron, iron will go into solution; if the impurities are positive, they themselves will dissolve and the iron will remain immune. The *role* of the *free* dissociated hydrogen derived from the water (as against *combined* hydrogen to be considered shortly) is of a catalytic nature. The free hydrogen is negative to the iron and by its contact effect causes its solution. The product of ordinary electrolysis of water by an electric current is two atoms of hydrogen and one of oxygen; the slow reaction of rusting results, apparently, in the formation of an atom of hydrogen and one of hydroxyl; that a difference of this nature should exist is not surprising; as we have already seen, different rates of oxidation produce different oxides. Once the iron is in solution, or

on the point of solution, it will be oxidized* by any free oxygen present.

With rise of temperature, the readiness of iron to oxidize increases. Hot iron decomposes steam, yielding an impure hydrogen, and is oxidized; corrosion is brought about by a similar action, but very much slower, voltaic electricity taking the place of heat. The first cause of corrosion, therefore, may be the electrolysis of water, followed by an electrolytic or catalytic action of the nascent hydrogen on the iron.

ACTION OF OCCLUDED GASES

Occluded gases must next claim attention. Graham found that iron cooled in hydrogen absorbed 46 per cent of its volume. John Perry in 1872 ⁽¹⁷⁾ detected the presence of hydrogen in steel. Ledebur found 0.0017 per cent of hydrogen in a soft open-hearth steel. These observations are of interest because, hydrogen being negative to iron, it will, as already stated, promote its solution and corrosion. The electrolytic activity of hydrogen was pointed out by Roberts-Austen ⁽¹⁸⁾.

According to Lenz, 45 per cent of the absorbed gases in iron may be hydrogen, the balance being carbonic dioxide, carbonic oxide and nitrogen in about equal proportions. According to F. C. G. Muller ⁽¹⁹⁾ about 67.8 to 90.3 per cent of the gas in steel is pure hydrogen.

It is a well-known fact that iron or steel containing occluded hydrogen, due to pickling in acids, is hardened to a considerable extent and is readily oxidized while in that condition; thoro washing and neutralizing of the acid will not correct the hardness nor the readiness to oxidize. Gas occlusion by this method may, normally, reach 12 times the volume of the iron, proving that most of it must be alloyed or in a liquid or solid state. The greater proportion of this absorbed gas is hydrogen and it must, necessarily, be as impure as that

(17) JI. I. & S. Inst. Yr. 1872, p. 240.

(18) *Fifth Report, Alloys Research Comm., Inst. Mech. Engrs., 1889.

(19) Deuts. Chem. Gesell., vol. XII (1878), p. 11.

which rises in the pickling vats, containing, therefore, hydrogen sulfide, arsenide, etc.

On the other hand, electrolytically produced iron, which is quite difficult to corrode, is hardened to a considerable extent by the absorption of hydrogen during its deposition. The hardness of electrolytic iron is 5.5 as against 4.5 for ordinary iron. According to Cailletet (²⁰), electrolytic iron will hold as much as 250 times its own volume of hydrogen and the alloy containing 0.028 per cent (by weight) of hydrogen will scratch glass. This absorbed hydrogen must be relatively pure, and while this may preclude electrochemical activity among the gases themselves it can hardly have much bearing on the difference of behavior between it and pickled iron, when exposed to corroding agencies.

The hydrogen contained in pickled iron can be almost entirely baked out of it at a low temperature; not so with the hydrogen absorbed electrolytically. This tends to show that in the pickled iron, the gas is not so permanently or stably combined—if combined at all—as in electrolytic iron. Furthermore, the great volume of the gas taken in by the electrolytic iron shows that a very large percentage must exist in solution as an alloy with the iron. The co-existence of three states of matter has been supported by Graham, Wiedermann and Spring. While there may be just as much free dissociated hydrogen contained in the pores of both classes of iron and the tendency to rust from that cause may be the same, yet the larger amount of hydrogen-iron alloy in the electrolytic iron may resist corrosion much better than iron alone. The quality of resistivity to corrosion is intimately connected with the rise in electrical conductivity which is brought about by the chemical union of hydrogen with metals. Hot iron when quenched in water absorbs hydrogen, and Richards and Behr (²¹) have found that the electrode potential was raised by 0.15 volt, the nature of the gas being apparently the same

(²⁰) C. R., vol. LXXX (1875), p. 319.

(²¹) T. W. Richards & G. E. Behr Jr. *Zeits. Phys. Chem.*, Mar. 5, 1907.

as that which is absorbed in the presence of nascent hydrogen and therefore by electrolysis. The hydrogen taken up by finely powdered iron reduced at a low temperature was not found to affect the e. m. f.; we may infer that the physical conditions attending the production of this iron were insufficiently powerful to cause the alloying on which the change of e. m. f. seems to depend. Dr. Steinmetz finds that electrolytic iron has a very high hysteresis loss, but attributes it to occluded nitrogen.

From an examination of all these facts, it would appear that the increase of potential due to the alloyed hydrogen in electrolytic iron overcomes the effect, as an electro-negative catalyzer or otherwise, of hydrogen in a free ionic state only. In all classes of iron the hydrogen exists in both conditions, free and combined, just as carbon does in pig-iron, but the proportion of hydrogen-iron alloy in electrolytic iron is very much greater than in the other metals. Hydrogen, like carbon, when present in a free state will by contact action promote corrosion; like carbon also, when chemically combined with the iron it will resist corrosion, but if the alloy is unevenly distributed the pure iron in contact with the alloy will be attacked.

According to Roberts-Austen, silicon, manganese and aluminium prevent the escape of hydrogen from iron; Ledebur claims ⁽²²⁾, however, that brittleness after pickling, due to hydrogen, is greater if the combined carbon is high, while silicon has the reverse effect; he is in accord therefore with Troost and Hautefeuille ⁽²³⁾, who claim that silicon diminishes absorption. These seemingly opposite statements may be reconciled by assuming that while silicon may reduce the absorption of hydrogen, it will also retard its subsequent removal, just as non-conductors which absorb heat with great difficulty will, on that very account, retain it the easier. Manganese is said ⁽²³⁾ to greatly increase the absorption of the

(22) Mitt. Kon. Tech. Versuchsanstalten, Ber. Yr. 1890. Suppl. I. 1907.

(23) An. Ch. & Ph., 5e S., vol. VII, p. 1155.

gas while diminishing that of carbonic oxide which is, in any case, very slight. Manganiferous pig-iron retains more gas than does ordinary pig.

Pressure applied during the solidification of metals—as, for instance, in the Whitworth process—prevents the escape of the gases. They can be driven out by heating, preferably *in vacuo*, or locally by machining or drilling; the combination is, therefore, not a very close one. To drive the gases out of pig-iron, a temperature of 800 deg. C. is sufficient. Malleable iron contains more carbonic oxide than hydrogen and it is retained with greater energy. Steel is said to absorb somewhat less than cast-iron, and wrought-iron less than cast-iron; these differences are, in great measure, no doubt, functions of the porosity.

Occluded gases, and especially hydrogen, must not be lost sight of when dealing with the problem of corrosion. Hydrogen is the lightest and, therefore, kinetically the most active of elements; it is in a way, a sort of universal catalyzing “daemon,” an extravagant statement to the ear, perhaps, but with some merit of suggestiveness; all chemical reactions take place in the presence of hydrogen, and it is the only element of which this is true. Hydrogen, which seems to form the main ejection from the sun, and may be regarded as closest to the primordial element from which, according to recent well grounded theories, all other elements may proceed, is unique in many of its properties; it seems to stand apart from the other elements in many ways. These differences are, in many cases, attributable to the great activity of its molecules in proportion to their mass, hence, for instance, the distinct character of its curve representing the value of $p v$ under different pressures.

The diffusion thru a finely porous material which gives rise to dissociation, is similar to, if not identical with osmosis; in osmosis the porous membrane causes dissociation resulting in chemical effects which are the basis of important reactions and, among others, of organic growth and life.

Hydrogen will pass thru platinum and red-hot iron (Ste.

Claire-Deville) and its ready dissociation, which was demonstrated in Winklemann's important study of its diffusion thru palladium ⁽²⁴⁾ suggests a belief in its breakdown, under conditions of common occurrence, into free and active atoms, ready to take the first opportunity offered of entering into a combination. The condition of most common occurrence is, as we have seen, the contact of dissimilar substances. The occlusion of free hydrogen in coal-dust, wheat-dust, zinc-dust and other dusts, will go far to account for their detonation by spontaneous oxidation. These dusts act in the same way as does spongy platinum on certain gases which it ignites by simple contact. A porous material like iron or steel should have a similar effect, but its action would be slow and progressive instead of sudden; instead of spontaneous oxidation we get slow oxidation, rusting.

We thus have additional reason to believe that free dissociated hydrogen ions, generated by the electrochemical action on moisture of iron in contact with its impurities or other substances exterior to itself, induces by catalytic excitation or an electrical effect of its contact with the iron, the solution of that iron as free ferrous ions which unite with free oxygen to form rust.

THE DIFFERENCE BETWEEN IRON AND STEEL

The principal difference between iron and steel lies in the carbon content. Iron having over 0.04 per cent of carbon is usually called steel; if there is less than about 0.15 per cent, it is known as a mild steel. Save in the arrangement and distribution of the constituents, it cannot be said that, chemically speaking, there is any sharp line of demarcation between iron and steel, but the processes of manufacture are different and the two metals have therefore different physical properties.

Steels, with the exception of the very mild ones, are susceptible to being hardened, and it is well to note that steels harden by changes in the carbides, whereas chilled iron is

(24) *An. Phys. Chem. Wied.*, vol. 6, p. 104, and vol. 8, p. 388.

hard because of a change in the structure of the surface from crystalline to amorphous, or nearly so.

Carbon is present in iron and steel, either as microscopic flat crystals of graphite, or as carbides of iron of which a number of varieties are known, more or less distinct from each other. The most common one is *cementite*, a definite compound, Fe_3C ; *pearlite*, an intimate mixture of cementite and ferrite (pure iron) forms the bulk of most steels and *martensite* is the carbide produced by sudden cooling. Sulfur, phosphorus and silicon are present as sulfides, phosphides and silicides. Manganese, which is added as ferro-manganese in the process of manufacture to prevent the occlusion of gases, is always present, either alloyed or in combination with the non metallic impurities. In special steels there may be nickel, chromium, tungsten, molybdenum, vanadium, etc. If the impurities are not dissolved in the iron they will separate as eutectics; this will depend in great measure on the heat treatment and mode of cooling.

THE STRUCTURE OF IRON AND STEEL

The normal structure of iron and steel is crystalline; fibrous iron is a misnomer, the fibrous appearance is due to the way in which the crystals draw out from each other in the direction of their main axes when the metal is fractured. The more slowly and uniformly the heating and cooling have been carried out, and the less interference there has been by mechanical distortion, the more regular and small will the crystals be; these crystals always lie in the direction of the heat waves passing out in cooling; they are, therefore, at right angles to the contour planes of the piece; it is on this account that sharp angles are to be avoided in cast metal work, as they cause a sudden change of direction in the position of the crystals. When cast-iron is "chilled" it appears to be set in a more or less amorphous condition, hence its lack of flexibility.

A change in the crystalline structure of iron may be brought about by shock or continual vibration; the fracture becomes coarser and there is a simultaneous loss of strength;

the iron is said to be *crystallized*. The strains which alter the mechanical condition of matter are: crushing, tensile, flexional and torsional. The factors governing variations in the results will vary according to the moment of the strain, or its average intensity multiplied by the period during which it acts. The effects of strain will also vary in different parts of the same piece from differences in the original heating, lamination, forging or cooling which it may have undergone. Shearing, punching and other operations will alter the structure; the walls of a cold-punched hole are unfit for threading because they are desaggregated, hence they should be drilled or reamed out. Swaging, unless performed gradually and at very high speed, will have a tendency to crush the material and make it "short," whereas light, rapid swaging and drawing thru dies will tend to interlock the crystals. If annealing is required after drawing wire and sheets, it is because the crystals are not as regularly and snugly packed by exterior mechanical means as they are by the crystallogenic forces which act during cooling from high temperatures. It is evident, then, that all manufactured goods must be more or less heterogeneous in their structure.

RELATION OF STRUCTURE TO CORROSION

It is found that, apart from chemical and voltaic causes, corrosion will vary according to the structure of the material and the mechanical treatment to which it has been subjected. It is also known that metals in large masses will not corrode as rapidly in proportion to the surface exposed as will smaller masses of the same composition and in the same physical condition. The reasons governing these facts are still obscure notwithstanding the many plausible theories which can be advanced.

Hard cast-iron is less corrodible than soft cast-iron of similar composition ⁽²⁵⁾, and it corrodes faster if cooled irregularly than if cooled uniformly and slowly. The inner portions being more uniform in texture, corrode more uniformly

(25) W. J. McAlpine, Trans. Am. Soc. C. E., vol. 1 (1868), p. 23.

and slowly (Mallet). The more porous the material, the more rapidly will corrosion proceed and the more deep and destructive will it be. Blowholes of any size invite rust. It has been found that iron gun-barrels corrode more rapidly in wet weather than those made of compressed steel (W. A. Adams). As first discovered by Kalischer, metals conduct electricity better when their structure is crystalline; an amorphous metallic foil which has been rendered crystalline by careful heat treatment will become a better conductor. Increased conductivity implies better resistance to corrosion.

The microscopic porosity of iron and steel has been shown and even measured by Thorner ⁽²⁶⁾. Under ordinary circumstances, water cannot pass thru the pores and fissures in iron, on account of their capillary action, but a high pressure will overcome this capillarity as shown in the "sweating" of hydraulic presses. The absorption of gases likewise proves the porosity of iron and steel. At high temperatures all metals absorb gases, losing part of them again upon cooling. As already stated, all manufactured iron and steel goods have to undergo some form of heat treatment and are found to contain hydrogen, nitrogen and sometimes carbonic oxide.

Carelessness of manufacture which tends to heterogeneity, is an invitation to corrosion and in itself goes far to explain why modern steel, which is tortured into shape at such a high speed that the molecules are not permitted to readjust themselves, is said to be more corrodible than the metals produced a generation ago; in those days iron and steel were produced in small quantities, without the addition of other metals, and were rolled slowly and allowed to cool naturally. The internal strains due to mechanical treatment are not to be confounded with the unevennesses in the distribution of the impurities due to segregation in cooling; these mechanically induced strains are really equivalent to straining the metal beyond the elastic limit which, as will be seen later, makes it more corrodible. Moreover, the tonnage-craze from which the quality of product in so many industries is to-day suffering,

(26) Stahl u. Eisen, vol. VI.

is causing to be placed on the market a great mass of material, only a small proportion of which is *properly* inspected, which is not in proper condition to do its work—rails and axles which fail in service and steel skeletons for high buildings which may carry in them the germs of destruction and death.

EFFECT OF STRESS ON CORROSION

"The effect of stress on the corrosion of metals" is the title of an instructive paper by Thomas Andrews, published in 1894 ⁽²⁷⁾, in which the results of extensive electrolytic tests made in saline solutions are recorded. In all classes of tests, tensile, torsional and flexional, the results were of the same nature; the unstrained parts were, by galvanometer readings, shown to be electro-positive to the strained parts and hence more subject to corrosion. On the other hand, according to experiments made in France that same year, if iron and steel are strained beyond their elastic limit, the surface corrodes with greater rapidity along the lines of deformation, where molecular cohesion has been broken down and the metal been made more porous. The author's own observations of over-strained bolts confirm this view, and it is a well-established fact that the metal around punched holes will rust more rapidly than that around drilled holes, because the degrees of strain differ.

Dr. Charles F. Burgess found ⁽²⁸⁾ that in steel strained tensionally and torsionally to just below the point of rupture, the strained parts corroded very much faster than the unstrained; the unstrained ends being cathodes, bubbles of hydrogen were given off from them under water. These results in no way invalidate those of Andrews; Dr. Burgess worked with pieces strained beyond the elastic limit and they had undergone permanent structural deformation, whereas Andrews worked within the safe limits allowed by engineers, where no permanent deformation within a long period of time is to be feared.

(27) Proc. Inst. C. E. Yr. 1894, p. 356.

(28) Trans. Am. El-Chem. Soc., 1908.

In recent experiments made by E. Rasch ⁽²⁹⁾, it was found that during tensile tests of brass and mild steel, within the elastic range the metal became cooler and beyond the critical point or elastic limit it became hotter. A loss of heat is to be expected during structural breakdown and its connection with the change of electrical conductivity is evident. Some years ago A. Witkowski found ⁽³⁰⁾ that in a strained metal there is an increase of electrical resistance in the direction of the strain.

All these observations go to prove the claim that mechanical treatment, by setting up uneven strains in different parts of finished pieces, will create variations of potential which will promote rusting. Whatever the composition of the different inner parts of the metal may be, and apart from any action which may be due to difference of composition, if there is a difference of molecular aggregation, it will promote the rusting of one or other of those parts. Action, power, everything knowable depends on difference of potential, and any chemical or physical difference between two portions of matter in contact must give rise to a difference of potential and a flow of electricity.

If straining a metal below its elastic limit by exteriorly applied mechanical means will make it electro-negative to the same metal unstrained, the strains set up by chilling or hardening should have a like effect; the metal should resist corrosion to a greater extent and promote the corrosion of more positive metals in contact with it. This is found to be the case. Eighty years ago Daniel observed that a certain steel was dissolved by hydrochloric acid five times as rapidly when unhardened as it did when hardened; this is an indication of what we may expect with the agents of corrosion. Prof. Chas. E. Munroe ⁽³¹⁾ mentioned the case of a cold-chisel, tempered at the end, which had been dropt into an engine-room channel-way of the S. S. Triana in 1874; when found, some years later,

(29) Preuss. Akad. Wiss. Ber., vol. 10 (1908), p. 210.

(30) "Effect of strain on electric conductivity": Trans. Roy. Soc. Edin., vol. XXX (1881), p. 413.

(31) JI. Franklin Inst. Yr. 1883, p. 302.

the hardened part was not corroded, but the soft part was, and especially so at the line of immersion in tempering which was clearly defined; at this point the contact-action was, of course, most pronounced; had the chisel been hardened thruout, it would, no doubt, have rusted all over; as it is, however, the soft part protected the tempered end, just as zinc will protect iron under similar circumstances.

"What becomes of the energy of a coiled watch spring when it is dissolved in acid?" is supposed to be one of the many unsolved mysteries of Science. The energy of the coiled watch spring is indicated by a slight shift of its potential towards the negative end of the electro-chemical scale, resulting in an increase of e. m. f.; when the spring is put in acid, the energy is expended in retarding the action of the acid and is equivalent to a drop of temperature which would restrain chemical action. The energy of the spring, as increased e. m. f., counteracts the energy of the acid; it is expended and disappears as work of a negative character.

COMPARATIVE CORROSION OF IRON AND STEEL

From a theoretical standpoint, steel, being negative to iron, should be the least corrodible of the two. As a general thing, results of tests between iron and steel have, in the past, resulted in favor of the iron; in most cases, the experimenters were undoubtedly looking for the defeat of the new material, steel, and their state of mind helped them to find it. There are, however, a large and ever increasing number of contrary observations recorded, especially where the tests have been carried out on a large commercial scale and with qualities of recent manufacture. The opinion one is led to form from a careful examination of recorded observations is in agreement with that of Ewing Matheson ⁽³²⁾, namely, that properly protected steel and iron rust to about the same extent, the steel doing so more uniformly; this is, of course, subject to the variations of structure already referred to, and those of chemi-

(32) Proc. Inst. C. E., vol. 69 (1882), p. 1.

cal composition, especially as regards metallic impurities, which will be considered later.

A most important paper was presented before the Institute of Civil Engineers in 1881 by David Phillips ⁽³³⁾, "On the comparative endurance of iron and mild steel when exposed to corrosive influences"; excellent tables are given and the general conclusions favor iron. A distinction must here be made between the cast and wrought metal: cast iron will not rust as readily as wrought iron unless the skin is removed, in which case it will rust faster.

It must be borne in mind, as a limitation to all results adduced, that while the initial rusting may be greater with either material, iron or steel, the rates of progression may be different and may bring about a complete reversal in the final result; the material which rusted faster at first may outlive the other. This is especially apt to be the case with forged, rolled and drawn metals. Future tests should, therefore, either be carried out to destruction, as advocated by Howe, or else to the point at which failure of the material in service would result from loss of useful area.

The most radical difference between iron and steel is the slag which is always present in the iron; while this slag may protect the metal immediately beneath it, its contact effect on the exposed iron surrounding it must more than counterbalance this slight advantage. But while this may be the most radical difference between the two metals, the most important one for the present discussion is the difference between the amount and composition of the carbides of iron.

The carbides of iron have a greater specific heat than iron itself; this implies a high resistance to corrosion; the difference varies directly as the carbon content and is, according to Meuthen ⁽³⁴⁾ 0.0011 for each 0.5 per cent of carbon. According to these investigations, the specific heat of cementite is 0.1581, whereas that of ferrite is 0.1432; these values check up closely by Kopp's law of molecular heat. A galvanic current

(33) *Proc. Inst. C. E.*, vol. 65 (1881), p. 73.

(34) *Metallurgie*, vol. 5 (1908), p. 173.

must be created by contact of the carbides and the ferrite. A steel containing about 1 per cent of carbon is practically a compound of carbon and iron; it is a most intimate mixture of ferrite and cementite, known as pearlite; on this account it does not pit readily; if by quenching from a high heat it is converted into austenite or martensite, this tendency is further inhibited. The author has found that in the case of two identically similar disks of steel, cut one after the other from the same bar, and exposed together for about two years to ordinary agencies, the unhardened disk had 69.1 per cent of its surface corroded, whereas the hardened disk had only corroded over 56.8 per cent of its surface; the difference is not great (20 per cent), but it should be mentioned further, that the rust on the hardened disk was of a darker shade than that on the unhardened disk.

Iron contains very little carbon; it is therefore a loose mixture of ferrite and carbides; there are spots of carbide scattered about because there is not enough carbon to permeate the mass thruout and form an alloy as in the case of steel; each particle of carbide is a center for the promotion of rust.

INFLUENCE OF MODERN CONDITIONS

The prejudice existing against steel may be due to the changes in the conditions surrounding the use of iron and steel, especially the composition of the waste gases of combustion which pollute the atmosphere and the employment of electricity for lighting and transportation. To quote Prof. H. M. Howe ⁽³⁵⁾: "The fact that steel has come into wide use simultaneously with a great increase in the sulfurous acid in our city air and of strong electric currents in our city ground may well lead the practical man, be he hasty or cautious, into inferring that the rapid corrosion of to-day is certainly due to the new material of to-day, steel, whereas, in fact, it may be wholly due to the new conditions of to-day, sulfurous acid and electrolysis."

This prejudice may also be due to the fact that, whereas

(35) "Corrosion of iron and steel": Am. Soc. Testg. Mats., 1906.

the iron of some years ago was more homogeneous and freer from slag than the iron of the present day, the steel which is now manufactured is perhaps more homogeneous than that which was made during the early years of the industry, when only small masses were handled. In puddling, working on a small scale will give a better iron, freer from impurities, but in steel making, working on large masses of metal will, within certain limits, assist the diffusion of the components by maintaining the metal thruout at a more even and higher temperature for a longer period of time.

CORROSION IN AIR

Iron will not corrode in air unless moisture is present, and it will not corrode in water unless air is present. This rule applies to salt-water also; R. Adie found ⁽³⁶⁾ that corrosion did not take place in salt-water if air or oxygen was excluded, and that alcohol containing oxygen but no water would not cause corrosion, all of which accords with the generally accepted theories.

* Iron having a specific gravity of 7.8, produced in the laboratory, as against 7.3 for commercial pig-iron, is slightly oxidizable in moist air, but iron of a specific gravity of 8.14 produced in the electric furnace, is scarcely at all ⁽³⁷⁾. This merely bears out previous statements.

The agents present in the air which accelerate rusting, especially in or near cities where much fuel is consumed, are numerous, but sulfur dioxide and soot are probably the most destructive because together, in the presence of moisture, they conspire to produce sulfuric acid. The action of these two agents is most marked in railway tunnels and bridges. Wm. Kent has studied the action of sulfur dioxide ⁽³⁸⁾; an analysis of sooty rust from a railway bridge showed the presence of sulfur dioxide, sulfuric acid, carbonic acid, chlorine and ammonia. Valuable papers on the decay of materials in tropical

(36) Proc. Inst. C. E., vol. IV (1845), p. 323.

(37) Genie Civil, vol. 9 (1886), p. 247.

(38) Jl. Franklin Inst., Yr. 1875, p. 437.

climates were presented before the Institute of Civil Engineers in 1864 ⁽³⁹⁾.

CORROSION IN FRESH WATER

The impurities in fresh water vary with the locality. Rivers flowing thru industrial towns will contain hydrochloric and sulfuric acids and acids due to the decomposition of organic matter; all are highly corrosive.

Carbonic dioxide, air and excess of oxygen, all of which will accelerate corrosion, are present in all waters to a varying extent. Silica and alumina are without direct chemical effect. The variable impurities are as follows: carbonates of lime, iron and magnesium; sulfates of lime, potassium and magnesium; nitrates of lime and potassium; lastly, the chlorides of sodium, potassium and magnesium which accelerate corrosion to a considerable extent. Salts which, like sulfates and chlorides, hydrolyze in solution to an acid reaction, promote rusting to a greater extent than when they remain neutral.

Water near the surface is more corrosive than lower down, because of the larger percentage of dissolved carbonic dioxide and air. Alternations of wetting and airing will increase the rate of corrosion, and on this account the most vulnerable part of a ship's hull from the outside is that part known as the wash-space; continuous immersion is less destructive.

All and any impurities in water will accelerate corrosion; if the rule of uneven composition promoting the corrosion of iron is true, it must apply to the medium also. A heterogeneous medium must, necessarily, be the seat of voltaic currents, the effects of which would be to supply the hydrogen ions required to induce corrosion. On this theory, any soluble—and possibly, even, insoluble—substance would promote rusting in water, even if it were without direct chemical effect on the iron; if any other substance is present which will attack the iron, the action will be hastened, as in the case of carbonic acid which has already been discust.

In the case of ironwork at the mouth of a river, where the

(39) Proc. Inst. C. E., vol. XXIV (1864), pp. 1 to 37.

water is brackish, strata of different degrees of salinity are to be found; on this account the rate of corrosion is particularly rapid at the point where the water is most salty; it is, on a large scale, the effect suggested as taking place in each drop of every non-homogeneous medium.

Rain water is relatively pure, but even it will contain salts dissolved from the dust in the air, which increase its conductivity and rusting properties. Theoretically pure water would be a non-conductor and could not, therefore, serve as the electrolyte in the process of rusting.

CORROSION IN SALT-WATER

In sea-water the proportion of chlorides is very much greater than in fresh water; moreover, some ammonia and the bromides of magnesium and iodine, all of them powerful aids to corrosion, have to be reckoned with. Sewage, which is almost always present near the mouth of rivers, supplies sulfates, nitrates and organic matter. According to records, the most salty seas are the Mediterranean and Dead seas, and the least salty are the Baltic and the Black seas.

Saline matter in water decomposes in contact with iron which fixes the negative elements; it also serves to increase the conductivity of the water considered as an electrolyte and, as already suggested, increases the heterogeneousness of the medium, resulting in galvanic action in the medium itself which may supply hydrogen ions. The most extensive and complete investigation of the action of sea-water on the metals of ships is due to Robert Mallet (⁴⁰), and he has published some very important tables.

When cast-iron is left in sea-water for a long period of time, it undergoes a remarkable change, being converted into a pseudomorphous mass of a black substance resembling plum-bago. As far back as 1822 it was known that slightly acidulated water would have this effect on iron, and 40 years later Dr. Calvert found this to be the case with salt water also. Guns from the wrecks of the Royal George and the Royal

(40) Trans. Inst. Nav. Arch., vol. XIII (1872), p. 90.

Edgar, which had been under water 62 and 133 years, respectively, were found to have become black and soft, so that they could be cut with a knife, and when brought up into the air they absorbed oxygen so rapidly that they heated up. They must have been extremely porous. Cast-iron pipe used for conveying salt-water has been known to undergo the same transformation ⁽⁴¹⁾. A piece of an iron ship's heel-post, which had suffered considerable decomposition of this nature, was found by David Mushet ⁽⁴²⁾ to be of the following composition:

Carbon dioxide and moisture.....	20.0	per cent.
Protoxide of iron (FeO).....	35.7	"
Silt or earthy matter.....	7.2	"
Carbon	41.1	"

Mallet attributes the conversion of the iron into a plum-bago-like mass to the action of the carbonic dioxide present in the water. It may be noticed that the very slow oxidation yields the oxide lowest in oxygen; it has been stated elsewhere, on other grounds, that the faster oxidation takes place, the higher the oxide will be.

CONTACT-ACTION IN SEA-WATER

Some tests were made in 1882 by J. Farquharson ⁽⁴³⁾ on six plates of iron and six of steel; these were immersed for six months in Portsmouth Harbor, six of each separately, the other six as connected couples; in this way the comparative corrosion of the iron and steel was obtained and also the increase of corrosion due to galvanic action between steel and iron. The following table gives the losses observed in ounces and grains:

(a)	Steel	{	in contact.....	{	0-427
	Iron				7-417
(b)	Steel	{	separate.....	{	3-340
	Iron				3-327

(41) Trans. Am. Soc. Mech. Engrs., vol. XVI, p. 416.

(42) Proc. Inst. C. E. Yr. 1840, p. 3.

(43) Trans. Inst. Nav. Arch., vol. 3 (1882), p. 143.

(c)	Steel	}	in contact.....	}	0.297
	Iron				7-770
(d)	Steel	}	separate.....	}	4.000
	Iron				3-190
(e)	Steel	}	in contact.....	}	2-337
	Iron				6-000
(f)	Steel	}	separate.....	}	4-157
	Iron				4-570

These results, which were confirmed by Mr. W. Denny from his experience in the case of the S. S. Ravenna, are interesting to analyze. They show that in two cases only did the steel corrode to a greater extent than the iron, but the difference is so slight that for all practical purposes it can be said that the steel and iron of the experiments (ship-plates) were equally affected. They also confirm the theory that the combination of steel and iron, which is quite frequent in practice, is detrimental to the iron, but protects the steel which is the negative partner. They also throw light on previous observations and lead to the conclusion that good homogeneous iron and steel are about equally corrodible. As we shall see later, the advantage which steel possesses over iron is due to the fact of its not pitting so deeply.

Iron in contact with non-metals will also suffer from galvanic action, as shown in the case of a bolt which was corroded almost entirely thru at the junction of pieces of elm and pitch-pine, which it held together ⁽⁴⁴⁾, and the case mentioned by Matheson of a piece of iron on a bridge which was corroded to a knife edge where it came in contact with wood.

The effects of electrolytic action are clearly demonstrated by the results secured by Mallet in a series of experiments which he undertook in order to ascertain the "amount of corrosion in equal times in clear sea-water of a unit surface of wrought iron plate exposed in electro-chemical contact with an equal surface of the following metals electro-negative to it, as compared with the corrosion of the same surface of the same iron exposed *alone* for the same length of time:"

(44) Proc. Inst. C. E., vol. XII (1852), p. 229.

	Relative Corrosion.
Iron plate alone.....	8.63 per cent.
In contact with: Brass (Cu_2+Zn)	29.64 “
Copper	42.79 “
Lead	47.90 “
Gun-metal (Bronze) ...	56.39 “
Tin	74.71 “

In connection with the above table, the valuable fact is mentioned that the brass alloys of composition $\text{Cu}_8+\text{Zn}_{17}$ to $\text{Cu}_8+\text{Zn}_{18}$ are without galvanic action on iron in sea-water. This explains the incorrodibility of the alloy of iron, copper, zinc (and sometimes tin), which is known as Delta Metal, and which, tested in conjunction with wrought iron and steel, showed remarkable resistance under test, as follows ⁽⁴⁵⁾:

	Wrought Iron	Steel	Delta Metal
Loss.....	45.9	45.45	1.2 per cent.

The first copper-zinc alloy for the special purpose of resisting the action of sea-water was patented in 1832 by G. F. Muntz. Muntz Metal is used for bolts, valves, etc., and for sheathing ships; its composition is 2 parts zinc to 3 parts copper. Tobin bronze is similar to Delta Metal, but contains tin and lead.

THE CORROSION OF SHIPS

The interior of ships is subject to various agents of corrosion. At certain points the temperature is higher than at others, and escaping steam keeps the atmosphere moist; the bilge-water, also, is of a highly corrosive character; the coal abrades the sides of the vessel, holds moisture in contact with them and induces the formation of sulfuric acid if sulfur dioxide is present, besides, coal is, in the presence of sea-water, strongly electro-negative to iron. Some cargoes and the fermented or decaying remnants of old cargoes are likewise aids to corrosion. Cement has been used for coating the ship-plates on the inside, but this prevents examination of the hull, and it

(45) Gesundheits-Ingenieur, Yr. 1888, p. 235.

is porous to moisture and gases. Steel lining-plates are perhaps preferable.

CORROSION OF RAILS

The case of steel rails is an interesting one, showing, as it does, the effect of vibration on rusting. A rail which has been in service but has been laid to one side, will rust all over, but especially at the ends where the vibration of the fish-plates has removed the mill-scale, and on the smooth top of the head. On the other hand, a quite remarkable fact, which has been universally confirmed and can be easily observed by anyone, is that a rail while *in service* will not rust nearly as rapidly as one which is lying out of service. The rusting takes place in proportion to the service, and lines over which fast trains pass frequently, causing much vibration, will practically not rust at all, whereas the rails of turnouts or sidings, which undergo less service, and that of a slow nature, will rust to a certain extent. One observer (J. M. Heppel) has reported the case of some rails at Madras, India, which lost 3 lbs. to the yard lying in the yard exposed to the sea air, while the rails in service nearby were not perceptibly affected.

The top of a rail is compressed and smoothed down in service by the grinding of wheel tires, for there is always a certain amount of slip, especially during acceleration and retardation. Galvanic action between the smooth head of the rail and the rest of it has been suggested to explain this immunity from rust, but it is not at all likely that the foot would owe its protection to the thin stratum of denser metal so far removed from it. If that dense skin on the top of the rail were not crushed beyond its elastic limit, it would, on the contrary, tend to accelerate the corrosion of the steel in contact with it.

The real reason for this difference of behavior seems to lie in the observed fact that oxidation is apparently arrested, or at least greatly retarded, by vibration ⁽⁴⁶⁾. Explanations seem to stop at this point, but a simple theory can be built on the

(46) Edwin Clark: Proc. Soc. C. E., Yr. 1868, p. 554.

assumption that the vibration causes a shedding of the rust as soon as it is formed on the spots that are not protected by mill-scale, and there is, therefore, no acceleration of the action due to the accumulation of spongy and electro-negative rust. The average speed of corrosion of a vibrating body would be that of the formation of a first film of rust. Most of the actual rust on rails is probably due to the rapid evaporation of rain on the surface. In the case of rails in service, the first film of rust would be confined to bare spots and cracks in the mill-scale and the vibration would prevent its working its way under the mill-scale as would happen if the rail were at rest.

The top of the rail being denser might be expected to resist corrosion better when the rail is out of use; such is not the case, however. The surface has not only been subjected to hammering and crushing, but also to abrasion and rolling, and it has become short and crackelled and sometimes exfoliated; once laid aside, the smooth top of an old rail rusts very rapidly.

THE CORROSION OF TUBES

The carefully acquired experience of the National Tube Co., of Pittsburgh, teaches that the use of steel in place of iron—at least in the United States—for the special purpose of tubing, is to be preferred; the tendency of the steel to pit is somewhat less than that of iron and it welds at the joint fully as well.

The joint investigations of H. M. Howe and Bradley Stoughton confirm these results. It must be borne in mind that the conclusions apply to skelp material only. They are further corroborated by experiments recently made by T. N. Thomson (⁴⁷), who finds that iron and mild steel pipes corrode about equally, the steel having, however, the advantage in the all-important matter of pitting. In a test of three pieces of wrought iron and three pieces of mild steel pipe conveying hot water during about one year under conditions identically the same, the iron pipe lost by rusting 20¾ oz. in 9 13/32 lbs.

(47) Domestic Engineering, vol. XLII (1908), p. 67.

(13.4 per cent), and the steel pipe $24\frac{7}{8}$ oz. in $9\frac{11}{32}$ lbs. (15.6 per cent). The experimenter did not stop short at these figures and argue therefrom, as all his predecessors had done, that the steel pipe was inferior to the iron pipe as a merchant article, altho evidently slightly more corrodible; he estimated the degree of pitting by averaging the measured depth of the five deepest pits in each piece and thence he calculated the number of days the pipe would remain sound and not show a leak; there is no evidence of his having taken into consideration the fact that the internal pressure would cause a leak before the metal was pitted thru; however, the proportions, as shown in the following table, would hold good:

Steel	850.4 days	Iron	780.5 days
	780.5		759.7
	759.7		686.5
	<hr/>		<hr/>
Average	796.9		742.2

The steel pipe was therefore 54.7 days, or $7\frac{1}{2}$ per cent, more durable than the iron pipe. Hot-galvanized pipe was found to last about 20 per cent longer than the ungalvanized; this result applying to a few pieces of similar origin and tested under conditions where galvanized pipe is generally considered unsuitable, is of little value. If it were correct, galvanizing would not justify its cost.

Mr. Thomson also draws the following conclusions from a large number of observations collected from all parts of the United States: That in the case of pipe buried in the ground and conveying steam or hot water, the exterior corrodes rapidly, but when the pipe is not buried, and unless air and other gases be removed from the water, the interior is corroded more rapidly than the exterior.

The tests of Howe and Stoughton, and the evidence which they have collected, is of great interest. Of ten different tests made by different observers in different places, seven resulted decisively in favor of steel; in the other three cases the results were very slightly in favor of the iron, but in only one of the latter was the material of modern manufacture. The tests

which resulted in favor of steel were as follows, all except the two first being carried to destruction: Seven months in hot, aerated salt-water; sixteen months buried in dampened ashes; exposed to sulfuric acid coal-mine water; in railroad interlocking and signal service; in locomotive boiler service. It was also found that steel tubes made in 1906 pitted much less than those of 1897 from the same makers, indicating the superiority of modern steel over that of some years back in this particular respect. Badly made steel will evidently corrode faster than a uniform product, and the question of the comparative corrosion of iron and steel should not be judged from the behavior of a poor quality; unfortunately, persons afflicted with mental hustling always generalize exceptions.

The Riverside Iron Works found that iron boiler sheets corroded faster than steel sheets when buried in soil which was kept moist with a solution of carbonate of soda, nitrate of soda, chloride of ammonium and chloride of magnesium, which are the most active corroding substances commonly found in water; the results were as follows:

After 23 days	Iron loss.....	0.84 per cent.
	Steel "	0.72 "
28 days later	Iron loss.....	2.06 "
	Steel "	1.79 "

Boiler tubes in service will suffer severely if exposed to the action of fatty oils which, even if perfectly neutral, have a strongly corrosive action on iron in the presence of steam (48). Cottonseed oil, which is used as an adulterant of cylinder oils, must be avoided.

CORROSION OF WIRE

In the case of wire, the consensus of experience seems to be just the reverse from what it is with pipe. In his report on "The Corrosion of Fence Wire" (49), Dr. Cushman quotes the opinion of a concern which is a very large consumer of wire,

(48) A. Mercier: *An. des Mines*, Yr. 1879, p. 234.

(49) *Farmers Bull.* No. 239 (1905), U. S. Dept. Agric.

that "Bessemer or mild steel wire will rust or deteriorate much more rapidly than iron wire. In all probability, three times as rapidly." He also found that according to the unanimous opinion of farmers, modern steel wire fencing is much more corrodible than the old iron wire. It is difficult to see why there should be this reversal of properties for wire as compared with tubing, in view of the fact that steel wire has a harder skin than iron wire because, being less malleable, and being harder to draw thru the dies, the packing of the material at the surface is more marked. This is easily proved by treating pieces of steel and iron wire with an acid; the acid eats out the metal on the ends according to its degree of porosity, and it is found that the steel wire shows a denser and better defined skin than the iron. In the case of iron, the honeycombing extends much closer to the edge. The skin seems to resist the action of the acid in the ratio of its density. The same effect of acids may be observed with all rolled material, notably sheets. The greater corrodibility of steel wire must then be due to peculiarities of chemical composition or other causes. In its investigations, the Division of Tests of the Department of Agriculture found, as would naturally be the case, that modern steel wire was, on an average, much higher in manganese than the old iron wire.

INFLUENCE OF THE IMPURITIES IN THE METAL

All non-homogeneous metals and therefore all commercial irons and steels, are doomed to decay unless adequately protected. Of the impurities in steel, the non-metals, with the exception of sulfur, seem to protect. In the case of metallic impurities, those which, like manganese, are themselves more liable to corrosion than the iron, will act unfavorably; others, like nickel and chromium, which are not so sensitive, will protect the iron with which they are alloyed, notwithstanding the fact that by mechanical contact they hasten the rusting; if unalloyed they act adversely, creating centers for pitting. Eutectic areas create centers for corrosion.

The nature and the amount of the impurities in steel have

a marked influence on its corrodibility. Carbon, inasmuch as it will allow hardening, will act as a protection, provided it is combined with the iron and uniformly distributed; high carbon steel is less corrodible than mild steel or iron.

Precipitated iron rusts more slowly if mixed with clean charcoal dust than when by itself, altho there is no favorable current set up; a test made by the author showed 16 per cent oxidation as against 18.4 per cent for the iron by itself; part or all of this protection is due, no doubt, to the absorbing power of charcoal for gases and to purely mechanical protection, but if powdered manganese be mixed with the iron, corrosion of the latter proceeds if anything more rapidly, altho it affords the same mechanical protection as does carbon, and is itself more oxidizable. The gray cast-iron, in which combined carbon is deficient, rusts more rapidly than other grades. Spiegeleisen⁽⁵⁰⁾ resists corrosion better than cast-iron because it is dense and high in carbon. Prof. Howe calls attention to the mechanical protection afforded by carbon *as rusting proceeds*, in the following words⁽⁵¹⁾: "As steel is gradually corroded away, more and more of its surface should come to be composed of cementite, and this fact should tend to retard the corrosion of steel, because cementite should protect the underlying free iron or ferrite." And elsewhere: "The cementite is in such extremely minute microscopic plates that the eating away of a very small quantity of the iron from above them ought to bring very nearly the full proportion of this cementite to the surface." It may be stated further that the definite compound, cementite, is much harder than iron—6.5 as against 4.5—and that it is soluble only in boiling hot acids. The resistivity to acids is always an indication of the degree of resistance to corrosion.*

(50) R. Ackermann: Dingl. Polyt. JI., vol. 246, p. 377; also W. Parker: JI. I. & S. Inst., vol. 1 (1881), p. 39.

(51) Am. Soc. Testg. Mats., 1906; Iron Age, Yr. 1906, p. 2047.

*This statement, broad as it stands, is incorrect. Reference to the Discussion will show that the relation of acid corrosion to ordinary rusting is very debatable. Further investigation leads the author to the belief that a relation does exist, but only when acids, highly diluted with ordinary aerated water, are used. This agrees with Mr. Unger's statement in the Discussion.

Dr. Dudley found ⁽⁵²⁾ that the presence of coal-gas in the ground materially retarded the corrosion of wrought iron pipe buried in it. In one test at Nashville, the presence of the gas reduced the rate of corrosion by one-half.

Graphite in iron, which is equivalent to uneven distribution of carbon, may promote rusting, but graphite applied to the outside is considered as second to red-lead only as a protection for iron work (Archbutt); this protection is, no doubt, purely mechanical, altho Mr. E. G. Acheson claims that steel, if immersed in water containing deflocculated graphite, does not rust as when the graphite is not added.

Phosphorus and silicon both appear to retard corrosion, and this effect may, as in the case of carbon, have some connection with their hardening qualities, or cold-shortening power. If, however, they are present in patches, like the oft-occurring phosphide eutectics, the softer parts, thru contact action with the parts rich in phosphorus and silicon, will be destroyed all the more rapidly. Some authors have claimed that these two elements increase corrosion, but there is no evidence to support the contention apart from the case of uneven distribution which will make any of the impurities rust promoters to a greater or lesser extent. The fact that common iron does not rust as rapidly as the better grades has been attributed by some to the greater percentage of phosphorus in the former.

Dr. W. L. Dudley discovered, some years ago, that segregated manganese formed centers of corrosion, and it is a generally accepted fact that steels high in manganese are peculiarly liable to oxidation; if the proportion is small and uniformly distributed the effect is inconsiderable. The effect of manganese is corroborated by many reliable authorities ⁽⁵³⁾. The mixing of finely divided iron and manganese and subsequent exposure to oxidizing agents, will result in increased oxidation of the iron, the manganese itself being oxidized more rapidly than the iron; if placed in water the electrolytic action

(52) *Progressive Age*, vol. 26, p. 137.

(53) Abel: *Proc. Inst. C. E.*, Yr. 1881 (Disc. Phillip's paper); Reynolds: *Proc. Inst. C. E.*, Yr. 1881 (Disc. Hadfield's paper).

is evidenced by an appreciable and continuous disengagement of hydrogen. If the metals are alloyed the alloy is more electro-positive than the iron by itself and therefore more readily corroded. Up to a certain percentage, manganese *dissolved* in iron will increase the electrical resistance of the metal, and the loss of conductivity may reach 50 per cent (Cushman). This fact is, no doubt, intimately connected with its corrodibility, the broad rule being that the better conductor a metal is the less it is liable to corrosion; the conductivity of a metal is always reduced by the addition of a less conducting metal. It is known that manganese salts fix oxygen on certain compounds, and that even the solid salts at suitable temperatures hasten the oxidation of many substances; the metal itself will precipitate iron from its solutions and it is reasonable to infer that with iron going into solution in the presence of oxygen, if there is any manganese present, it will aid its precipitation as an oxide. As silicon has the property of hardening manganese, a small percentage doing so to a considerable extent, the influence of manganese in promoting corrosion may be modified by that element.

According to R. Dubois (⁵⁴), some ferro-manganese originally carrying 79.99 per cent of manganese was partially disintegrated by exposure to the weather. The powdery part held 82.17 per cent of manganese and the mass had shrunk to one-half of its original bulk; this goes to prove the instability of the combination between the two metals.

The combination of manganese and sulfur shows a larger difference of potential to iron than manganese alone. The sulfur in steel will unite more readily with the manganese than with the iron, giving a gray sulfide. Some valuable investigations of the effect of manganese sulfide on the quality of rails have quite recently been carried out by Dr. Henry Fay and J. E. Howard (⁵⁵). These investigators show that manganese sulfide separated in the form of fibers is a source of danger in

(54) Bull. Assoc. Belge Chim., vol. 15 (7), p. 281.

(55) Am. Soc. Testg. Mats., 1908; also Eng. News, vol. 60 (1908), p. 94.

steel rails, so that, apart from reasons relating to corrodibility, the combination of high manganese and high sulfur is to be avoided as a measure of safety.

The protection afforded by paints containing manganese dioxide (MnO_2), even after their removal, seems to be due, not to the power which the salt possesses of decomposing hydrogen peroxide, but to the creation of a passive condition due to the formation of a film of black oxide (Woods); by using a very active oxidizing agent in a paint, it is claimed that a slight inoxidation may be brought about and rusting inhibited; some tests of this theory made within recent years have not borne it out. If a Venetian-red (Fe_2O_3) paint is used, there cannot be any protection, even in theory—and almost anything can be done in theory—all metals are electro-positive to their own oxides, and on this account paints containing oxides of the metals to be painted are undesirable from a galvanic standpoint. An ideal method for protecting steel against corrosion would consist in giving it a perfectly homogeneous surface before painting, either by removing slag, manganese, sulfur and other impurities chemically, or by depositing electrolytic iron upon it, using a depolarizer to take care of the free hydrogen.

COMPARATIVE CORROSION OF ACID AND BASIC STEEL

Alexander G. Fraser, in a paper read before the West of Scotland Iron and Steel Institute in 1907, gave the results of an extensive investigation of the relative corrodibility of acid and basic steels.

Excepting in the sulfuric acid test, the acid steel was a trifle less attacked than the basic; this may have been due to the manganese being higher in the basic steel, altho the phosphorus was lower. In the case of the sulfuric acid test, the basic steel resisted far better than did the acid steel; the skin of the basic steel plates was scarcely attacked, whereas most of the acid plates were badly corroded. Mr. Fraser suggested that this might have been due to the carbon being in a different condition in the two steels and a sort of case-hardening

of the basic plates having taken place during rolling. From the figures given in the table it would appear that the popular notion about the excessive corrodibility of basic steel is unfounded.

INFLUENCE OF THE ELECTRIC CURRENT

Interesting tests of the effect of an electric current on the speed of corrosion of a steel plate were made by Mr. Gardner, of the Scientific Section of the American Paint Manufacturers Association ⁽⁵⁶⁾; the results of the normal tests without current under different conditions are worth comparing with those of earlier experimenters, but the increase in the rate, due to the passage of a current of $1\frac{1}{2}$ volt, is specially worthy of attention. The following is a summary of the results obtained by Mr. Gardner:

1	Distilled water boiled.....	0.0482
1-A	Same with electric current.....	0.0870
2	Distilled water and oxygen.....	0.0601
2-A	Same with electric current.....	0.1211
3	Distilled water and ozone.....	0.0768
3-A	Same with electric current.....	0.1155
4	Pure air oxygen and nitrogen.....	0.0492
4-A	Same with electric current.....	0.0911
5	Pure air, with ammonia: Oxygen, nitrogen and ammonia	0.0406
	(Little oxide precipitated. Color dark.)	
5-A	Same with electric current.....	0.0758
	(Little oxide precipitated. Color dark.)	
6	Pure air, with ammonia: Oxygen, nitrogen and carbonic acid.....	0.1030
	(Color of oxide brighter than any of foregoing.)	
6-A	Same with electric current.....	0.1941
	(Color of oxide brighter than any of foregoing.)	
7	Pure air with ammonia and carbonic acid....	0.0921
	(Color of oxide brighter than any of foregoing.)	
7-A	Same with electric current.....	0.1876
	(Color of oxide brighter than any of foregoing.)	

In each case the action seems to have been about doubled in its intensity by the passage of the current.

(56) JI. Franklin Inst., Yr. 1908, p. 459.

IRON AND STEEL EMBEDDED IN CONCRETE

Reinforced concrete is undoubtedly the building material of the future, because of the wide distribution of cement material and also because this combination of concrete and steel has proved itself within the last few years the best for every purpose and from all points of view except, possibly, that of beauty of form. The one and only serious objection which has been raised against it is the permanence of the reinforcement; it is a question of paramount interest.

In reinforced concrete construction, the steel reinforcement gives the material the requisite quality for undergoing flexional strains under which concrete by itself would fail, as would natural stone, notwithstanding its high resistance to crushing. To take advantage of its qualities, the reinforcement must be placed below the concrete, altho additional reinforcement may be required on the upper part to take care of negative bending moments. The mortar which is applied to the other side of the reinforcement—the lower side in the case of floors and beams—must be sufficient to protect it against fire and corrosion. The lighter coating is usually $1\frac{1}{2}$ inch or more in thickness, depending on its composition, and therefore its ability to resist the disintegrating effect of fire applied for a long time; its composition should be such as to afford full protection against corrosion. It is remarkable but true that but little attention is paid to the latter consideration, altho it is fully as important as the protection against fire.

The majority of tests which have been undertaken to secure data on the corrodibility of steel in concrete, have resulted in the broad conclusion that when properly mixt and applied, Portland cement concrete is an ideal protection against rusting. There is a well-known case of iron hoops embedded in cement for 26 years, which were found unimpaired and with the blue mill-scale intact⁽⁵⁷⁾. Whether or not, as claimed by Breuille, cement removes any rust which may have existed on

(57) Proc. Inst. C. E., Yr. 1839, p. 37.

the metal when it was embedded, is of secondary importance compared to the action it may have on the unimpaired metal.

Neat Portland cement is known to be an excellent protection against rusting; it has been successfully used as paint for the protection of large structures, notwithstanding its lack of flexibility. On account of this quality it is well to endeavor, wherever possible, to fill in and around the reinforcement and in immediate contact with its surface, with a concrete high in cement and holding a smaller percentage of small gravel or broken stone than what is to be laid above it; it should also be applied very wet to insure good contact and the formation of a film of neat cement on the surface of the reinforcement; for the protective coating a rich mortar, as wet as can be used, is advisable.

Professor S. B. Newberry has explained as follows the protective action of Portland cement: "Portland cement contains about 63 per cent lime. By the action of water it is converted into a crystalline mass of hydrated calcium silicate and calcium hydrate. In hardening it rapidly absorbs carbonic acid and becomes coated on the surface with a film of carbonate, cement mortar thus acting as an efficient protector of iron, and captures and imprisons every carbonic-acid molecule that threatens to attack the metal. The action is, therefore, not due to the exclusion of the air, and even tho the concrete be porous, and not in contact with the metal at all points, it will still filter and neutralize the acid and prevent its corrosive effect." This explanation will no doubt satisfy the followers of the carbonic-acid theory of corrosion, but the fact will remain that at points where there is no contact between the cement and the metal, corrosion does quite often take place; however, the protection against carbonic acid afforded by the cement must be an efficient retarder of corrosion. An insoluble carbonate is an excellent impermeable screen against corrosive influences, and its value is well illustrated by the remarkable passivity of sheet-zinc roofing which has been weathering for scores of years on thousands of buildings in European cities.

With many styles of reinforcement, it is difficult to employ a selected strength of mix in immediate contact with the steel; with reinforcements made from sheet metal it can, however, be readily done. Professor Chas. L. Norton has made tests which show that, while neat cement affords perfect protection to steel, concrete does not; it is thus of the very greatest importance that the cement be sufficiently wet to insure a film of neat cement forming on the surface of the reinforcement, and that the concrete be everywhere well rammed.

As far as subsequent rusting is concerned, it would seem to be of little importance whether the reinforcement be clean and free from rust or not at the time of embedding, provided the concrete lie close to it and form an impermeable skin over it; it is, however, an important consideration to secure proper adhesion of the steel to the cement. Especially is this necessary in the case of wire which must not draw thru the cement in case an anchorage fails or it is rusted thru at one point. Galvanizing or painting the reinforcement is a pure waste of money and both are liable to introduce agents of corrosion, such as chlorides, metallic oxides and organic acids. A dip of tar-asphaltum would perhaps be beneficial.

Cinder concrete is more porous than that which contains a stone filler, and opposes less resistance to shear, and for these reasons it is less desirable in reinforced work; it is still a matter of some doubt if the small amounts of sulfur and iron oxide which are present in the cinder can have any effect worth considering on the reinforcement; it is, however, not advisable to use it around the reinforcement, especially where, as in the case of wire, "splitting" is to be avoided. For similar reasons it is best not to use slag cement until it has been definitely proved that steel is no more liable to rust in it than in genuine Portland concrete.

According to Breuille, if water is allowed to pass thru the concrete, the neat cement film in contact with the steel will disappear and rusting will take place; it is thus advisable to waterproof exposed surfaces—as is always done in the case of roofing—or to use an opaque reinforcement such as specially

crimped or corrugated sheets; even then the water, if it cannot go thru, will work its way out laterally.

Cement has been used for the inside of ships to protect the hull against the internal corroding agencies which are the most severe. Barges, pontoons and even row-boats have been built entirely of reinforced concrete.*

There is a great deal of literature published on the subject of reinforced concrete and the conclusions to be derived from it are that it is safe to use modern rustable steel reinforcement provided it is clean, and a coating of neat Portland cement on its surface is insured by using a rich and wet mix with clean sand and trap rock, limestone or other hard and passive filler, in immediate contact with it, and avoiding voids by careful tamping. The fact that concrete structures are monolithic and become stronger with age and also because the factors of safety allowed are—and should remain—conservative, we are justified in feeling convinced of their permanence, even if thru carelessness during erection the reinforcements suffer a partial decay. It would be unwise, however, not to provide against such decay and to allow it to go to the length of total destruction.

THE INHIBITION OF RUSTING

By the inhibition of rusting is meant its restriction or repression, not its complete prohibition; inhibition means an extension of life for the iron; the protective effect is, sooner or later, overcome and clearly indicates that inhibition furnishes *something* to the iron, be it substance or physical state, which, under the attacks of corrosive agencies is slowly expended until destroyed or brought below the safe limit of protection.

Inhibitory treatments have the effect of rendering the iron or steel passive. Passivity to chemical action may have a mechanical or electrical cause. In some cases it seems to be due to the formation of a neutral screen between the corroding agents and the iron; in other cases it seems to be due to a zone

*This system was first used for boats and pontoons by Lambot-Miraval, a Frenchman, in 1850. The manufacture of reinforced concrete skiffs, sailing boats, floating stages, pontoons and barges has been successfully carried out by Gabellini, of Rome, Italy, since 1897.

of occluded matter or gas which affords galvanic protection. This last seems to be the nature of the protection afforded iron which has undergone any of the inhibitory treatments which have so far been tried.

The fact, pointed out by Dr. Cushman, that treated iron will take on an adherent coating of copper from a sulfate solution in less than one-sixth the time required when it is untreated, is sufficient proof that the electrolytic action which causes the precipitation of the copper has been intensified by the inhibitory treatment; the difference of e. m. f. between the copper ions and the iron is greater. The investigator points out further that the protective effect can evidently not be due to a film of oxide ⁽⁵⁸⁾.

That strong oxidizing agents would render iron passive, has been known for a long time. Prof. Bloxam in 1868 ⁽⁵⁹⁾ showed that iron which had been dipped in pure nitric acid for a length of time was not affected by the same acid dilute. The fuming sulfuric acid will have a similar effect. Arsenic and its derivatives likewise inhibit rusting ⁽⁶⁰⁾.

The best way to examine the subject of inhibition is to take advantage of the work of Dr. Cushman and analyze the following facts, expressed in his own words:

1°. "All substances which develop hydroxyl ions in solution, such as the alkalis or salts of strong bases with weak acids, to a certain extent inhibit, and, if the concentration is high enough, absolutely prohibit the rusting of iron."

2°. "No rusting occurred in any solutions of or above a strength corresponding to about 8 parts of potassium bichromate in 100 000 parts of water or about 2 lbs. to 3 000 gallons."

In both of these cases the objects treated were kept in the treating solutions. Potassium bichromate and chromic acid appear to be of benefit for retarding the inception of rusting, under proper conditions of concentration and condition of the surfaces treated.

(58) Cushman: Loc. Cit., pp. 21 and 23.

(59) Proc. Soc. C. E., Yr. 1868, p. 567.

(60) Lindet: C. R., Nov. 21, 1904.

3°. "No visible change is effected, for the polished surfaces examined under the microscope appear to be untouched. If, however, the polished strips are immersed in water, it will be found that rusting is inhibited for a matter of hours, days or even weeks."

The impossibility of detecting any change in the surface tends to show that no chemical alteration of the surface has taken place; the final overcoming of the protection by corroding agencies, shows that the attacks of those agencies exhaust the power accumulated by the treatment and that, therefore, some kind of destructive effect on whatever was left in the iron by the treatment, is taking place, until finally the metal loses its immunity and is corroded in the ordinary way.

4°. "If a polished surface, which has been rendered passive by immersion in bichromate, is heated to 100° C. for some hours, its passivity disappears and it again behaves in a normal manner."

5°. "A chromated strip of iron which is kept in a vacuum soon loses its passivity, whereas a similar strip kept under ordinary conditions remains passive for long periods."

These last two facts are strongly suggestive of the presence of an occluded gas, which can be baked out or diffused out in a vacuum.

6°. "The phenomenon of passivity is produced only by strong oxidizing agents or by galvanic contact when oxygen can separate on the iron."

As we have seen, when iron is anode and dissolves, it will rust, and hydrogen, which is negative to it, will be precipitated. In the present case we have the condition of oxygen being precipitated, showing that the iron is cathode. In the case of rusting we had free dissociated hydrogen inducing corrosion by its contact effect on the iron, now we have free dissociated oxygen inhibiting rusting by what we may well be allowed to surmise is likewise a contact effect. Hydrogen, which in itself is suggestive of reduction, is the *indicator* of the opposite reaction of oxidation, and oxygen, which suggests oxidation, is the indicator of reduction. This fact is very well

illustrated in the process of pickling by electricity ⁽⁶¹⁾, in which the metal to be pickled is put in a weak acid solution and connected as cathode in a circuit of low voltage; the scale is rapidly reduced.

7°. "According to Mugdan ⁽⁶²⁾, the passivity is due to lowering of the potential of the metal."

8°. "If polished iron is allowed to stand for some time in standard tenth-normal potassium bichromate solution, the oxidizing strength of the latter, as measured by its titration value, is slightly reduced without the solution of the iron or the production of any visible effect."

This bears out the argument that oxygen is absorbed by the metal and that, being positive to iron, its contact effect is to render the iron immune as cathode so that it will not dissolve; the positive partner of the couple thus formed is the object of the attacks of the agencies which cause the rusting of iron. As we have seen, hydrogen in a free condition is "the enemy"; the inhibitory effect is therefore destroyed by the union of the attacking hydrogen ions to the oxygen in the surface of the treated iron. When hydrogen has combined with all the oxygen the iron has lost its passivity and rusting proceeds.

9°. "In order to show beyond doubt that an oxygen electrode is formed by immersing iron in a strong solution of bichromate, the following experiment was made: Two polished steel electrodes were prepared and chromated by immersion for a number of hours in a strong solution of potassium bichromate. The prepared electrodes were then thrust tightly thru a rubber stopper which closed a flask which was then filled with pure, freshly boiled distilled water. The electrodes were then attached to the poles of a primary battery of about 2 volts potential. At the end of half an hour, altho the potential was not sufficient to disengage bubbles of gas and no visible change had occurred, the electrode which was connected

(61) C. J. Reed's patent.

(62) Zts. f. Elektroch., vol. 9 (1903), p. 454.

to the zinc pole of the battery had lost its passivity, the other retaining it."

Rapid depolarization has here been effected by a reversal of current; slow depolarization, which finally does away with the benefits of the treatment, is brought about by natural agencies.

Cushman's conclusions are that from the evidence, the passivity of iron is best explained as a polarization effect produced by the separation and retention of oxygen on the surface of the metal and that the protection afforded by certain oxidizing agents is electro-chemical and not mechanical. That if the rusting of iron is due primarily to the action of hydrogen ions, iron in the condition of an oxygen electrode should be more or less well protected from electrolytic attack.

We have gone somewhat further and examined the growth and decline of this so-called polarization and the facts disclosed all go to vindicate the electrolytic theory of corrosion.*

*An extensive bibliography of "Metal Corrosion and Protection" has been prepared by the Carnegie Library of Pittsburgh, copies of which may be obtained from the Librarian by forwarding two cents to cover postage.

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DISCUSSION

Mr. F. N. Speller: Mr. Sang has certainly brought this broad subject together in a very complete manner. There is only one point on which I would take issue with the speaker, that on the connection between solubility in acid and rate of corrosion. The history of this acid test started, perhaps, with the matter coming before the Committee on Corrosion of the American Society for Testing Materials, of which I happened to be a member. Whitney's experiments on the solution of iron had been repeated by Dr. W. H. Walker, Dr. A. Cushman proving that iron will go into solution without the presence of carbonic acid, and Dr. Cushman by his "Ferroxyl" test further showed in an interesting way that the electrolytic theory is the most rational explanation of the phenomena of corrosion.

It appeared to follow theoretically from this that the rate of solution in acid will be proportionate to the rate of corrosion. The point seemed so evident to some that it was decided to make mention of this method of testing corrosion in the report of this committee of two years ago. The precaution was taken, though, to point out that the fact noted had not been proved, that it was purely theoretical; the idea being to have a number of tests made at various places to aid which tentative specifications for making these tests were offered.

I had a talk over this matter with Dr. Cushman not very

long ago, but he now seems convinced that the acid test is not a reliable indication of the rate of corrosion for comparative tests. In conjunction with some others, we made some 200 tests on samples which had been previously corroded under natural conditions, and without going into details, I may say that only in a very few cases was there any connection whatever between the rate of solution in acid and natural corrosion.

The question of the effect of manganese, I think, is still open. No one so far as I know has offered any evidence to support the opinion that manganese in moderate amounts is going to increase the rate of corrosion. If precautions are taken as they should be to insure the uniformity of the manganese contents, there is absolutely no evidence to show that manganese in moderate amounts increases corrosion.

About two years ago I discussed the manufacture of tubes before this Society, and incidentally referred to the matter of the corrosion of modern tubes of charcoal iron and steel. At that time a certain number of results were given from laboratory and other tests which seemed to indicate that lapwelded steel tubes made under modern processes of treatment were somewhat superior to the older charcoal iron. It is hardly necessary to offer any more evidence along that line than what Mr. Sang has given, although I could go into details on a number of service tests that have been made since that time. We have complete service tests from thirty different railroads, made during the last two years, on charcoal iron and modern lapweld steel, which show that the steel corrodes more uniformly and somewhat less than iron. That is very satisfactory, and the National Tube Company has, as a result of a careful study of this question, concluded to abandon the manufacture of charcoal iron. What is required now is some reliable method of inhibiting or protecting metal from corrosion; this would seem to be the most fruitful field for discussion and experiment for the future.

The Author: I am very pleased, indeed, that Mr. Speller has given us some reliable information on the subject of the

ratio of corrosion under ordinary agencies and by acids. I have not found very much in the literature of the subject, but what there is would point to some ratio. In the course of ordinary laboratory investigations, I found that with pure acids there appeared, on the surface, to be some ratio. With commercial acids it is an entirely different matter. One never knows how they are going to act. One would have to know their exact composition and even then would hardly understand what was happening. But coming from an authority like Mr. Speller, new evidence is very valuable, indeed.

As to manganese, I think I said that if it is in very small proportions and evenly distributed it may not be detrimental, and that is my belief. But there are a great many very high manganese steels, especially wire, and I have seen some analyses which showed manganese very high and sulphur very high at the same time. Used for ordinary purposes, fencing, etc., I believe these to be highly corrodible.

Dr. K. F. Stahl: I can mention the following experience: We erected an addition to a building having corrugated iron sides, put on about 6 years before. The old corrugated iron from the original building was used again on the parallel side of the addition, while the two ends were covered with new corrugated steel. About eight years afterwards the steel sheets were badly rusted, but the older iron sheets were good yet. Both kinds of corrugated sheets were painted and repainted with the same paint at the same time. I blamed the manganese in the steel for the rapid oxidation, because I had observed a specimen of spiegeleisen, which I kept with minerals in an almost air-tight case, to rust badly. I did not make any experiments to verify this, but ever since when we bought corrugated sheets for siding or roofing, I specified iron, and demanded that the manganese should be below one-tenth of one per cent. We have used several carloads of these iron sheets in the last ten years, and they are all in good condition so far, much better than steel sheets purchased a year or two before we commenced to specify iron. Both kinds were repainted whenever they needed it.

I do not believe you can draw any conclusions from the way acids act on metals as to their ability to withstand rusting. When it comes to acids I don't think there is any difference between iron and steel. In tanks used for storing or transporting sulphuric acid, our experience seems to indicate that iron will last about the same as steel. Our older tank cars are all iron and the newer ones steel. Not long ago we dismantled an iron tank car, which had been in service about twenty years, mostly for 66° sulphuric acid. From time to time it had required repairing, a little hole would appear which we soldered up, and the car would run for six months or more before another hole appeared. After we dismantled it, I went inside and found that it was eaten in streaks; there were grooves in it running parallel and close together 1/16 in. deep, some as deep as 1/8 in. Finally, some of these grooves got so deep that they caused a leak, sometimes as small as a pin hole, which could be stopped with solder, the surrounding metal being quite strong. Quite a number of the steel tanks which I have examined have been eaten almost uniformly. We are dismantling a storage tank where the steel sheets are probably only 1/16 in. thick all around, they were 3/8 in. originally. This is a large tank, built only about ten years ago. It was used for 60° acid, which is probably more destructive to either iron or steel than 66°, and as the acid is pumped in and withdrawn daily there is more agitation and consequent action on the metal than in a tank car. Iron tanks may have parts that are still 1/4 in. thick and other parts that are eaten almost through, therefore, while more metal is dissolved in a steel tank than in an iron tank, they will probably need renewal after the same length of service. The rivets seem to go faster than the sheets. We have had any number of rivet heads eaten off entirely, so that the rivets could be pushed through with a slight tap of the hammer. This proves what Mr. Sang said, that stresses in iron tend to make it acted on more quickly and that if parts of a tank are of different composition, galvanic action will set in.

The Author: As to the different behavior of iron and steel sheets, I would point to a very well known fact, that when it

comes to painted sheets it is very difficult to judge, because iron takes the paint very much more readily than steel and that vitiates the conclusions. As to the case of the iron tanks corroding in streaks, that was due to the slag that was rolled out. That is the way iron sheets usually corrode. If we had a piece of that sheet, I think we could find the culprits.

Mr. R. B. Woodworth: My investigations on this subject are rather towards the prevention of corrosion than a study of corrosion itself. The problem that confronts me as an engineer is, given structural steel as it is and the workmen as we know them to be, what can we do to prevent corrosion and to lengthen the life of the steel?

We all know that corrosion takes place under certain conditions, that impure river waters, saline waters, waters carrying more or less high percentages of sulphuric acid, soils containing deleterious mineral ingredients, all have more or less corrosive qualities. These conditions we have to meet, and I am very glad that this problem has been brought before the Engineers' Society of Western Pennsylvania and that my own investigations into the prevention of corrosion will have the assistance of so careful a paper as the one to which we have listened this evening.

One of the most interesting facts in connection with recent researches into the corrosion of iron and steel is that our friends, the paint makers, have been compelled to take an intense interest in the subject and to set on foot investigations into the chemical and physical properties of the materials which they furnish for their own protection against unwise legislation, ultimately designed to insure the obtaining by the consumer of a pure product. I venture to predict that some of these days we will be able to buy paint just as we buy steel, subject to specifications as to quality, and that each can will be labeled with its chemical composition and that we will thus be enabled to obtain mixtures of which we will know, before their application, that the results will be in accordance with our desires. In the course of the investigations that I have been making on paint for the protection of steel mine timbers

exposed to sulphuric acid laden waters, I have had occasion to ask a number of paint manufacturers for some information as to the exact chemical composition of their paints as sold in the open market. I have been unable to obtain from them any information of this sort, and so far as I know there is only one paint manufacturer in these United States who is willing to tell you what he actually puts into his product. That being true, the proposition to a man who has to paint a particular piece of steel work is not very simple.

It may be interesting to state that I have in my possession a piece of iron that was put into the Mississippi River in the year 1863, and that is to-day in as good condition as when it was put in. It was painted with some kind of red paint which looks very much like red oxide of iron, and the paint is just as good to-day apparently as it was the day it was put on. The conditions there must have been extremely favorable to its preservation. The water of the Mississippi River at that point is probably pure and the iron was buried in the Mississippi River silt, sand or gravel so as to be protected from exposure to atmospheric conditions, and as a consequence there was nothing to make corrosion.

I have also a theory that so far as our own rivers are concerned, although they do carry a great deal of free acid, yet when the steel is placed sufficiently below the river bed as to get the advantage of the filtering action of the sand and gravel, we do not have to do with an acid laden condition, but rather with the condition of practically pure water free from contact with air, and I think we have every assurance to believe that the life of steel under such circumstances will be indefinite. I was told by the engineers who have charge of the construction of the Black Rock Lock at Buffalo, that the waters of the lake are not considered in any way dangerous and that steel of ordinary commercial quality in such installations may be expected to last for any reasonable length of time.

It may be interesting in this connection to refer to the characteristics of the different waters with which we have to deal. In looking up the subject, I have been very much sur-

prised to learn that river water does not contain any such large amount of free acid as I had supposed. The data, however, has not been gathered very completely, and it is possible future researches may give us more complete information. According to a report made by the United States Geological Survey, the Youghiogheny River at McKeesport during the year from September 6th, 1906, to September 6th, 1907, carried but 75 parts in a million of free sulphuric acid. At Elmira, N. Y., the Chemung River carries a proportion of total solids of 76 parts in a million composed of nitrates and chlorides without a trace of sulphuric acid, and with 500 to 26 500 bacteria in a cubic centimeter. Just above the anthracite basin, the Susquehanna carries 113 to 166 parts of total solids in a million composed of nitrates and chlorides and 1 980 to 2 750 bacteria in a cubic centimeter. The same river at Steelton carries 110 to 200 parts in a million of nitrates and chlorides, with bacteria running as high as 186 000 per cubic centimeter. Now, the presence of bacteria in river water means in a general way the absence of free sulphuric acid, for the two are not very friendly to each other, but there is a stretch of water between Steelton and the upper end of the anthracite basin where the water is entirely different and where the conditions so far as preservative treatment is concerned are quite serious. In this section the river from Nanticoke down receives the runoff from the mines, but farther down the effect of the different chemical constituents is to act as a coagulant with the deposition of the suspended coal and sulphuric acid bearing solids and consequent clarification of the stream. Three analyses of water run as follows:

No. 1—Total solids	792 parts in a million
	39 parts sulphuric acid
	79 parts iron oxide
No. 2—Total solids	1977 parts in a million
	150 parts sulphuric acid
	393 parts iron oxide
No. 3—Total solids	3003 parts in a million
	164 parts sulphuric acid
	143 parts iron oxide

I mention these figures only to show that each particular condition of the probable corrosion of steel would necessitate a different treatment, and it would be wrong to argue that the method used in one place will be sufficient for another, or that a method which fails under one condition is not, therefore, to be condemned for a different locality.

The deleterious action of mine water is due not only to the free sulphuric acid contained therein, but probably also to the amount of iron which it carries; all of which comes from the decomposition of the coal itself. Coal may contain sulphur in three forms, viz., as sulphate of lime, as sulphide of iron, or iron pyrites and possibly as organic sulphur. More commonly the drainage from the mines comes out in the form of protosulphate of iron, Fe SO_4 . On exposure to the air this salt, according to my authority, breaks up yielding hydrated oxide or free basic sulphate of iron which precipitates and gives a yellowish color to many of the waters of the small streams into which the mine drainage runs and sesquisulphate, or ferric sulphate, which remains in solution. This ferric sulphate, when brought into contact with metallic iron or steel, attacks it freely, and the metal is converted again into the protosulphate of iron. This in turn breaks up and the corrosive action repeats itself in the continued series until the supply of iron is consumed. In this way the corrosive action continues indefinitely and the formation of rust carries with it a continued increase of rusting surface and of rust making power.

The same condition is that which confronts us in the matter of scale in boilers, which is taken care of, in some cases at least, by the addition of soda ash in quantities sufficient to a little more than react with the ferric salts, and, when carbonates are present in sufficient quantity, to neutralize the action of the free acid; corrosion is practically out of the question, and the decay of the steel effectively prevented.

These are the conditions with which we have to deal and the problem for the paint manufacturer and the engineer is: Given a structural steel, which the world has looked upon for years as a standard material for all kinds of ferric structures,

and given unskilled workmen who put on preservative coatings on that material without especial care in its proper preparation, what will be the result of our endeavors and how can we best accomplish our purpose in making of that steel a permanent structure? There are two lines along which the solution will probably be reached. First, we may arrive, by our investigations, at a preservative material which will inhibit corrosion, but whose expense may be prohibitive. Dr. Cushman has told us that chromic acid is one of the chemical constituents which we can apply with beneficial results. Another and probably the more economical solution is to take pigments easily within reach and protect the material by some ingredient, such as red lead, which will adhere firmly and tightly to the steel, and then to protect that pigment by a second coat, or a third coat, which in turn is not attacked by acids.

Mr. J. S. Unger: My experience is that the addition of about $3\frac{1}{4}$ per cent nickel to a carbon steel reduces its corrosion by the action of solvents to much less than what it originally was. In some experiments we made we used three varieties of wrought iron, two of basic open hearth steel, one of Bessemer steel and one of nickel steel. We subjected them to various agents such as sea water, 10 per cent solution of boiling brine, 1 per cent solution of sulphuric acid and 1 per cent of ferrous sulphate, made to imitate a mine water, and the action of ordinary well water, or water that contained no free sulphuric acid, but contained carbonates and sulphates of lime and magnesia.

We found after treating them in the solvents for about a year, the actions ranked in about this order: Common pipe wrought iron was corroded the most, then a medium quality wrought iron, followed by a low carbon Bessemer steel; then by the best grade of wrought iron, then by open hearth steel, each of the open hearth steels being corroded to about the same extent. The material that was least corroded was open hearth nickel steel. Our object in testing the open hearth steels was to determine whether open hearth fire box steel of high or low manganese would show a difference in corrosion.

The plates under examination carried about 0.22 and 0.60 manganese. In the tests they were subjected to, we found very little difference. The carbon, phosphorus and sulphur contents were about the same in both plates, the difference being in the manganese. Further experiments along this direction led me to believe that the more impure the substance the more rapid the corrosion, or, in other words, the Bessemer steel will corrode more rapidly than open hearth steel; an acid open hearth steel will corrode more rapidly than a basic open hearth steel. Wrought iron, being a different sort of material than steel, some of the phosphorus and some of the sulphur possibly existing in two states, as that of sulphite, sulphate, phosphite, phosphate and sulphide or phosphide; they are heterogenous substances and it is difficult to draw a real conclusion from them. But we have found that in almost all cases the wrought iron will corrode more rapidly than steel. We have also found that on comparing high and low carbon steels made by the same process, such as high and low Bessemer or high and low basic open hearth steels, that the higher the carbon, other things being equal, the more rapid the corrosion.

I believe there is a current belief that wrought iron pipe and wrought iron roofing will last very much longer than steel. We carried on what might be called some practical experiments, completing them just a few months ago, but not with quite the accuracy of the preceding experiments. The experiments were as follows: We took two sheets each of several corrugated roofings, standard size, of as near the same gauge as it was possible to secure in the market, carefully polished, analyzed and gauged them, and placed them side by side on the roof of a mill building. There was a possibility of galvanic action between the sheets, but that was disregarded. The sheets were not covered with any protective agent. They were in a bad location where they would get the benefit of any gases coming from the heating furnaces and the exhaust steam from an engine. They were allowed to remain about three years when they were removed. At the expiration of that time the results were as follows: The three brands of wrought iron

of two sheets each had corroded until they were almost ready to remove. Some portions, especially where they lapped, had been corroded until they were almost like a net work and could be broken through readily by the pressure of one's fingers. On the high portion of the corrugations we found the wrought iron sheets still strong enough to resist a slight pressure; on the bottom of the corrugations they were practically corroded through. Of the steel sheets tested at the same time, and which were in fair condition, we found on analysis that what had been sent to us as open hearth roofing was really a moderately low phosphorus, low sulphur grade of Bessemer roofing; but we found that the three grades of steel roofing on the roof at the time, were better preserved than any of the wrought iron roofing. Further, it was noticeable that in the steel roofing the corrosion was uniform over the entire surface, while the iron roofing tended to corrode in streaks and spots. I had the slag determined in the three grades of wrought iron roofing. I supposed the sheets with the largest proportion of slag would be the least corroded. Unfortunately, it was attacked first, and was the poorest variety of the lot. Our slag determinations were really more in the nature of a determination of insoluble matter and not of oxides. I believe that in addition to the actual amount of insoluble slag in the material, consideration should be given to the amount of oxides that existed in the wrought iron. There are certain oxides which in the ordinary determination might go into solution and not be caught in the filter, and yet might exercise a protective influence on the material.

I confirm Mr. Speller's statement that the atmospheric corrosion tests will not compare with the acid solvent tests. In order to secure results quickly, one must adopt an acid test. The amount of time required is too long in a great many cases if less than a 5 per cent solution of acid be used for the tests. If one has the time he can work with a 1 per cent solution of sulphuric acid, but unless the solution is made extremely dilute, one does not get results that are at all comparable with the action of, say mine water or ordinary river water. I

believe the differences secured in results have been due entirely to the strength of the acid that was in the solution, a very dilute sulphuric acid seems to act more nearly like atmospheric conditions than a more concentrated one.

Mr. Whited: I notice that the railing on the city bridges rusts more rapidly than any other part of the bridge, that is, above the roadway, particularly when the sidewalk is paved with asphalt or floored with wood. I suppose that is due, in the case of asphalt, to the fact that the asphalt shrinks away from the steelwork, allowing the accumulation of filth, thus forming a center from which voltaic action starts and extends rapidly in all directions. In the case of wood, I suppose the acid in the oak, which is the usual material for bridge floors, starts corrosion, which is extended in the same manner as in the case of asphalt. Where cement sidewalks are used, the cement adheres closely to the steel and prevents the accumulation of filth and the above-mentioned action does not occur. Still, the railing rusts even then, more rapidly than the upper parts of the trusses. I suppose that is partly due to dirt from the hands and clothes of passers-by, and partly to the fact that most of the railing manufacturers use poor paint in their shops.

I would like to ask Mr. Sang if he can give us in detail the recipe which he says is used on the French railroads to protect their overhead structures, or at least give us a reference to it?

The Author: I am sorry to say I cannot give the nature of the mix, but I shall be pleased to furnish the information from the source from which I got it, and it can be inserted later.*

By a Member: You spoke of arsenic inhibiting corrosion. How much is it necessary to put in steel?

The Author: The arsenic was applied as arsenious acid in those tests made in France, and there was no evidence as to the amount absorbed. The arsenic was not in the composition of the steel, it was an application as in other inhibitory treatments.

*Original not available. See "Engineers' Hand Book of Concrete Reinforcement," American Steel and Wire Co., July, 1907, p. 36.

Mr. G. E. Flanagan: Mr. Sang, in his paper, laid stress on the necessity of getting very intimate contact between the cement and the steel in reinforced concrete. Most all of us have heard the same thing before, and it is well that we should hear it again, and be reminded of it frequently, lest we forget. There is probably no more vital feature in the whole problem of reinforced concrete construction. It seems strange that people in the present day engage in constructing such work and act as though they were oblivious of this fact, but many do. They seem to think, when they have the various special types of bars for armored concrete, which change the form of their section continually, or at least in a distance of 2 in. or 3 in., that the adhesion of the concrete to the armor is less vital. It would be well if that sort of notion could be entirely eradicated from those who have this work to do. I also noticed in the paper that the question of whether the bar is rusty when it is put in place has very little effect on the further progress of the rust on the steel. There are some very good builders of armored concrete who refuse to take bars as they come from the mill, but insist on their being exposed to the weather for a time in order that the bars may become rusted, as they claim that the cement secures a better adhesion than if the bars come fresh from the mill with the black scale upon them.

Mr. James O. Handy: The following data, from the records of the Pittsburgh Testing Laboratory, showing the superior resistance of a very pure iron sheet to corroding influences, may be of interest:

	G. C. Iron Sheet	M. C. Steel Sheet
Carbon	0.018%	0.09%
Manganese	0.024%	0.39%
Phosphorus	0.040%	0.103%
Sulphur	0.023%	0.053%
Silicon	0.036%	....
Corrosion ratios:		
Cold sulphuric acid (3.6%)..	100.	1600.
Air and moisture.....	100.	280.
Sulphur dioxide and moisture (cold)	100.	112.
Sulphur dioxide—strong solution in water.....	100.	108.

These tests show that in mine water the iron sheet would last much longer. In air it is superior to steel, but in a less degree. It resists the attack of sulphur dioxide but little better than steel. The air and sulphur dioxide tests are most rational for materials of construction.

FAILURE OF CAST IRON FROM ELECTROLYSIS

Two cases have recently been investigated by us. The cause of failure was not known at first. The iron had apparently remained of the original thickness, but had become soft like compressed graphite or stove polish in consistency and appearance. The failure occurred only in isolated spots. Analysis showed that half to two-thirds of the iron had gone, leaving the remainder as a black hydrated oxide. The carbon, phosphorus and silicon remained in their original ratios to each other. No other explanation than that of electrolytic solution of the iron is tenable. One case was that of a brine pump used for circulating calcium chloride solution in a refrigerating system. The other was a water main failing only in spots after 16 years' service. There was no rusting. The iron had been abstracted by weak electric currents assisted by saline matter in solution.

Mr. R. A. L. Snyder: The Telephone Company are vitally interested in the subject of corrosion. We have a great amount of metal surface exposed to the action of corrosion, both aerially and underground. Our messenger wire, cable clips, line wire, etc., are continually deteriorating. A large number of experiments have been made in our laboratory and the conclusions reached are that electrolysis is generally responsible for corrosion. After trying numerous combinations of metals and forms of alloys and coatings, the best combination we have been able to find is a zinc coating on iron (galvanizing). Zinc is electro-positive to the iron and when you scratch through the zinc coating it appears to be self-healing, i. e., the current seems to plate the zinc over the iron again. Tin-coated iron exhibits the reverse action, tin being electro-negative at the abrasive point. The iron not only rusts very

rapidly, but the rust usually extends under the tin coating. Corrosion is such an extensive subject that it deserves most careful study. I believe there will be something developed in the near future which will give a better protection for iron than the present galvanizing or metallic paints.

I would like to ask Mr. Sang if he has ever taken a piece of iron embedded in concrete and placed it in water, making the iron anode and the water the cathode and passed a small amount of current through it to see if it corrodes the iron. I tried this experiment and found that the iron corroded quite rapidly, but I do not know if I had the proper mixture of concrete for this class of work. I have always been rather skeptical as to the thorough prevention of corrosion in structural iron foundations set in concrete, especially if they are positive to the earth. To protect plunger elevator casings, which extend several hundred feet into the earth, we have taken the precaution to make them electro-negative to ground. I believe that the subject of electrolytic corrosion in its various forms is not appreciated by many engineers.

The Author: I have never tried the experiment referred to. I suppose you all know that it has been tried and is still being tried, to put large masses of zinc in the foundations of the steel work of skyscrapers. I have heard of it being done, but I never have heard the result. Perhaps our children will know about it.

Mr. H. S. Prichard: The writer listened with great interest to Mr. Sang's highly instructive address. The author has based his paper on such profound knowledge and treated his subject so comprehensively, that not much can be properly urged in criticism, and very little can be added to the information he has given. It is only where he departs from his theme, corrosion of iron and steel, to commend the superior virtues of reinforced concrete over other forms of construction, that the writer desires to take issue with him. Reinforced concrete has reached a high rank as a building material and occupies a wide field of usefulness whose boundaries have not yet been definitely determined, but, quite apart from beauty of form, it has

not proved itself the best for every purpose and from all points of view, as the author considers.

After pointing out the value of cement as a protection against rust, the author does well to call attention to the fact that concrete is not a complete protection, and the writer would emphasize this point as there is a tendency toward over confidence in this regard.

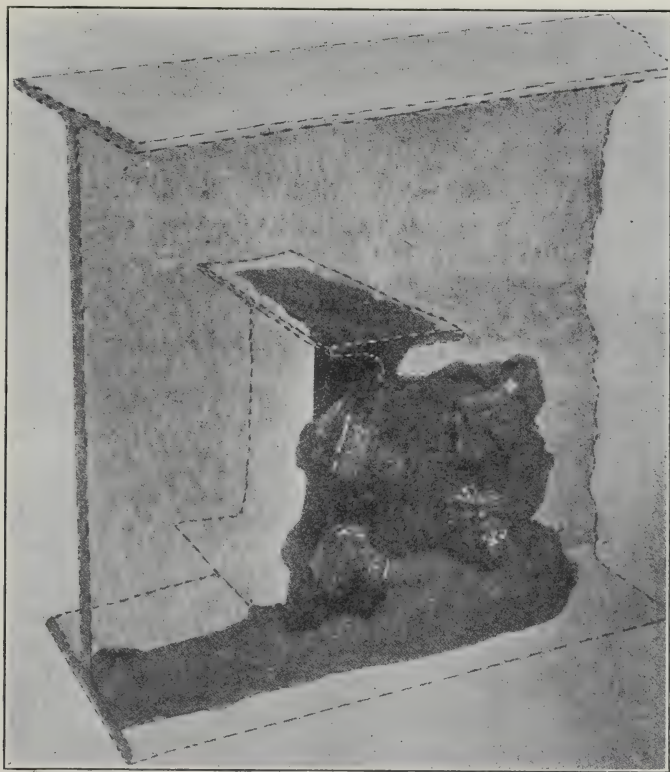
J. A. Fitzpatrick, in *Scientific American* of Nov. 28, 1908, p. 373, calls attention to the rusting of beams in the basement floor of the Eastern Power Station of the Brooklyn Heights R. R. at Kent and Division avenues, Brooklyn. According to Mr. Fitzpatrick, "the basement-floor construction consisted of 6 and 7-inch steel I-beams framing into 15-inch steel I-beam girders. Between the beams were segmental concrete arches, stiffened by a wrought-iron mesh center. These arches did not cover the bottom of the beams, but left the flange exposed except for an occasional coat of paint received in the early history of the station. The steel frame was erected by the Berlin Iron Company in 1890.

Considerable rust was noticed on the exposed beam flanges; and as some of these appeared to sag in the center, a section of arch was removed, to see the condition of the upper portions of the beams. In only a few cases was there any upper portion left, the steel having corroded to such an extent that the webs and top flanges had disappeared entirely, leaving only rust on the adjoining concrete. The floor, instead of being supported by the steel framing, was in reality carried by the three-inch slab of concrete covering the tops of the arches."

Mr. Fitzpatrick further states that he "investigated the locality, finding the following conditions to exist:

The condensers employ salt water in their operation, and much of this is ejected in the form of spray on all sides of the condenser pits. There being no chance of drainage, this has been allowed to settle for years in pools on the floor, and together with the exhaust steam from the engines above, which found its way into the cellar, the atmosphere in the space between the two floors was kept continuously moist. This mois-

ture was absorbed by the concrete arches, and held as if in a sponge, close against the web and upper flanges of the beams. The decomposition was probably slow at first; but as the chemical action progressed, a space was made between the steel and the concrete, leaving a space for air to enter, thus accelerating the chemical action. The exposed bottom flanges were in far better condition than the inclosed portions of the steel, this probably being due to the paint they received.



The wrought-iron bolts throughout the work were in an almost perfect state of preservation. This was also found to be true of the wrought-iron mesh centers under the arches.

The illustration reproduced here shows typical examples of the 6 and 7-inch beams framing into the 15-inch beam gir-

ders. The steel being worn to a knife edge on the flanges, and the small portion of webs remaining, evidently show the effect of electrolysis.

The almost perfect preservation of the bolts is also shown, and it will be noticed that the shop rivets are in better condition than the material in the beams. The bolts, as mentioned before, were made of wrought iron, but the rivets were of rather soft grade of steel, while the beams were of the hardest grade of steel that the writer has ever seen used in construction work. This leaves an open question as to whether the hardening elements in the high-grade steel, carbon and manganese, did not assist in the decomposition.

The main sewer draining the residential section of Williamsburg flows past the station on the north side emptying into Wallabout Creek a few feet away from the mouth of the intake tunnel which supplies the water for the condensers. Traces of chlorine have frequently been detected in the basement, and this has undoubtedly assisted in the decomposition of the beams."

The rusting of steel beams, under the circumstances described by Mr. Fitzpatrick, shows that concrete is not complete protection, and indicates the need of judgment in the operation of power and manufacturing plants, and in deciding on the construction to be used when water is liable to stand or play on the floors or walls of a structure, but for the ordinary run of buildings in which combinations of concrete and steel are not liable to be water soaked, it does not have much bearing on the question with which Mr. Fitzpatrick's article is headed, viz., "Is Concrete Steel a Permanent Construction?"

Stripped of technical phraseology, it may be said that combined moisture and air in contact with iron and steel is the prime cause of rust. It is, therefore, very important, in designing iron and steel structures and frames, to avoid, as far as possible, places where water or refuse can collect, and to arrange any metal, not permanently embedded in some protective material, so that it can be readily inspected and repainted on occasion.

Mr. J. A. L. Waddell, in a paper on "Nickel Steel for

Bridges," which was published in the September Proceedings of the Am. Soc. of C. E., gives, on pages 737 to 739 and 883 to 886, the results of two sets of comparative corrosion tests of nickel and carbon steels; one set made by himself and one made for him by the Osborn Engineering Co. In the cinder and locomotive gas tests, nickel steel showed the greater resistance to corrosion. In the salt test by Mr. Waddell, nickel steel showed decidedly the greater resistance, while the salt test by the Osborn Co. nickel steel showed slightly greater resistance up to 870 days, but carbon steel showed slightly greater resistance at the end of 900 days, when the test was discontinued. In the sulphuric acid test by Waddell, continued 160 days, carbon steel showed decidedly the greater resistance, while in the test by the Osborn Co., continued for 900 days, carbon steel showed only slightly greater resistance to corrosion.

The Author: In Mr. J. A. Fitzpatrick's article, quoted by Mr. Prichard, it is not mentioned whether the cement used was a natural or a Portland cement. From the date (1890) the chances are that it was a natural cement, which is not suitable if permanent qualities are to be secured. In my paper I very distinctly refer to *Portland* cement. Mr. Fitzpatrick does not give the physical condition of the concrete as he found it, and especially where it came in contact with the I-beams. It is difficult to judge, therefore, whether or not the work was properly done. Even with the best of cement and the best of steel, permanent qualities cannot be expected if the work is improperly put up. This is true of every process in engineering, and I do not think that the data furnished by Mr. Fitzpatrick is sufficient evidence that concrete steel is not a permanent construction. Where water or any corrosive liquids or gases are present, there is necessarily great danger of these liquids or gases seeping through the concrete and attacking the reinforcement. Under such circumstances it is poor judgment not to protect the surface of the concrete by some special treatment, as I pointed out in my paper. The qualities of reinforced concrete must be judged under normal

conditions; when conditions are not normal it is evident that special precautions must be taken.

Mr. R. A. Cummings: The engineering profession should be grateful to Mr. Sang for the careful manner in which he has presented this important subject. Every engineer has to do with some sort of a structure using steel, so that the information will appeal to a large number. To those identified with reinforced concrete construction, his assurance of the permanence of the reinforcement will be especially appreciated.

It is regrettable that his observations of the neglect of engineers to consider the corroding of steel in concrete should have been confined to the work of those who have doubtless been governed by indifference or commercial conditions. Nevertheless, the practice of the writer is to take precaution against the corrosion of the reinforcement. Wherever reinforcement is embedded in concrete that is submerged in water or subjected to moisture, the rods are completely coated by immersion in a bath of neat Portland cement immediately before being placed in the work. Portland cement is strongly alkaline and it has been stated in the paper that alkalis "absolutely prohibit the rusting of iron."

In addition to this statement, it is a fact that there are innumerable examples in existing works of complete prohibition of the rusting of embedded steel. Reinforcement, therefore, merits the full confidence of practicing engineers in the permanence of the steel reinforcement.

The accuracy of the statement in the paper preferring sheet metal to the many styles of reinforcement must be questioned, as it is not clear what is meant. It is doubtless true that the deformations of twisted and other irregular shaped rods is liable to cause air pockets to form around the reinforcement or to prevent an intimate contact with the concrete. But it is claimed by the venders of deformed rods that such occurrences are negligible owing to their mechanical bond obtained. Nevertheless, the writer would urge the use of plain rods of a uniform circular section as such rods offer no obstruction. Concrete in setting will shrink radially towards the surface

of a circle and grip the rods so the adhesion is all that good practice can demand. On the contrary, concrete does not adhere to a flat surface, but will arch itself and shrink away, leaving a space without contact with the sheet metal, plates or structural steel.

Galvanizing and painting with oil or tar must be avoided as defeating the adhesion of the concrete to the rods.

There is an immense amount of technical detail in connection with the design and construction of reinforced concrete which must be intelligently applied and conscientiously carried out.

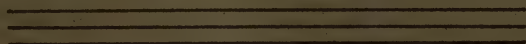
DISCUSSION OF PAPERS.

Members of the Society and also other readers of the Proceedings are urged to send to the Secretary written discussion of papers after publication, which will be printed in succeeding issues of the Proceedings. We believe that much valuable information may be presented in this way, and it is hoped that this feature of written discussion may be made a prominent one in the Proceedings.



THE FUNCTION OF OXYGEN IN THE CORROSION OF METALS

By WILLIAM H. WALKER



Scientific Section
Paint Manufacturers' Association
3500 GRAYS FERRY ROAD
PHILADELPHIA, PA.



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THE FUNCTION OF OXYGEN IN THE CORROSION OF METALS *

BY DR. WM. H. WALKER.

Professor of Industrial Chemistry, Massachusetts Institute of Technology.

The electrolytic theory of the corrosion of metals, from which point of view the role played by oxygen may best be discussed, has received the endorsement of so many able investigators working entirely independently, that further argument in its support would seem to be unnecessary. In volume two of the Journal of the Iron and Steel Institute of Great Britain for 1908, however, there appears as a report of a Carnegie Research Scholarship, an article on the Corrosion of Iron, by J. Newton Friend, in which the author proves to his apparent satisfaction that "the electrolytic theory of the corrosion of iron is untenable." Were it not for the authority which publications in the Journal of the Iron and Steel Institute carry, this communication would scarcely deserve even a passing notice. As shown later the reasoning employed is superficial and the experiments described are untrustworthy.

When a metal is placed in water or in an atmosphere sufficiently moist so that a film of water condenses on its surface, the action which may take place is essentially one of solution. Every metal has a tendency to pass into water solution in the ionic form, assuming a positive charge of electricity and leaving the metal negatively charged. To maintain electrostatic equilibrium an equivalent amount of positive electricity must leave the solution by the separation of hydrogen ions from the dissociated water in the form of hydrogen gas, charging that

* Paper read at the Fourteenth Annual Meeting of the American Electrochemical Society, New York City, October 30, 1908, President E. G. Acheson in the Chair.

portion of the metal on which the hydrogen separates positively, and leaving the solution negatively charged. An electric current is thus produced which is carried from one point on the iron to the solution by the escaping iron ions, and from the solution again to the iron by the separating hydrogen ions, and equilibrium again restored. The speed of this reaction depends, *first*, upon the escaping tendency of the metal itself, measured by its solution pressure; *second*, upon the concentration of the hydrogen ions, increasing as this concentration is increased; *third*, upon the ease with which deposited hydrogen ions can assume a gaseous state and escape or be removed from the metallic surface.

The solution pressure of the different metals, that is their tendency to assume an ionic form and pass into solution, varies from that shown by sodium or potassium where this escaping tendency or solution pressure is so great that instant decomposition occurs, to that of platinum or gold where we find the solution pressure so small that there exists no tendency to assume the ionic form. Between these two extremes we find all of the other metals, including the element hydrogen. For the purpose of the discussion of the electrolytic theory of corrosion and the part which oxygen plays therein, we can separate the metals into two divisions, viz., those which have a solution pressure less than hydrogen, as for example, copper, lead and mercury, and those which have a greater solution pressure than hydrogen, such as magnesia, manganese, zinc and iron. So far as this one factor is concerned, therefore, metals should be decomposed by water in proportion as their solution pressure is greater or less than that of hydrogen; but other factors enter into the reaction which introduce some important exceptions to this generalization.

The second factor influencing the rate at which a given metal will pass into solution in water and thus itself be decomposed, is the concentration of the hydrogen ions. In consequence of the positive charge which the solution assumes by virtue of the positive charge of the metallic ion which has entered it, there is set up with respect to the

metal surface an electrolytic double layer which arrests further progress of the solution. If there be present in the solution, however, hydrogen ions and the metal under discussion has a solution pressure greater than that of hydrogen, ionic hydrogen will pass over into the molecular condition giving up its positive charge to the metal, and leaving the solution negatively charged. An electric current will pass, thus breaking down the electrolytic double layer and so produce an electrostatic equilibrium which enables this cycle to be repeated. The result is that the metal continues to pass into solution and molecular hydrogen continues to be deposited on the metal other than the point at which it is dissolving. The ease with which the hydrogen ions can neutralize or destroy this electrolytic double layer depends on their concentration and varies from the case of pure water where the action is excessively slow, to that of a mineral acid in which the speed of the reaction is so rapid that hydrogen is set free from the surface of the metal as a stream of gas. Hence, in the case of a metal in contact with water, any reagent which increases the hydrogen concentration will accelerate the corrosion, while on the other hand, the reagent which will decrease this hydrogen concentration will diminish the rate of corrosion. Thus does the electrolytic theory of corrosion account for and explain the increased solution, or as we term it, corrosion, of the metal by such materials as are themselves acids, or which by hydrolysis, as for example magnesium chloride at high temperature, furnish an acid. This theory also accounts for the protective or inhibitive action of such materials as milk of lime, caustic soda, cement, etc., which by introducing a large number of hydroxyl ions into the solution, cause the hydrogen ions already there to disappear, on the other hand.

The third factor is the ease, due to lack of resistance, with which the electric current generated by the solution of the metal at one point and the separation of the molecular hydrogen at another, can pass from one of these points to the other. They may be infinitely close together or separated by quite a distance. Therefore, this theory demands that

solution or corrosion should take place more rapidly in water in which there is dissolved a trace of an electrolyte, than in absolutely pure water.

As a corollary of the last feature mentioned, viz., the resistance of the external circuit, follows the influence exerted upon the rate of reaction by the ease with which the molecular hydrogen, which separates or plates out upon the metal, may be removed. The resistance of a film of gas is relatively very large and if this hydrogen gas be not removed from the surface of the metal, the resistance thus introduced in the circuit may be so large that no appreciable current can pass, and therefore the reaction would apparently cease. It has been long known that hydrogen is much more easily liberated from the surface of certain metals, such as copper or platinum, than it is from certain other metals, as zinc or iron. It is also a recognized fact that hydrogen will unite with oxygen to form water much more easily from the surface of certain metals than from others. Hence, the electrolytic theory demands that the solution or corrosion of the metal should vary, other things being equal, with the ease with which hydrogen may be liberated from its surface and also with the ease or to the extent to which the reaction $\text{H}_2 + \text{O} = \text{H}_2\text{O}$ is catalyzed.

Mr. Friend, in the paper noted at the beginning of this article, rests his conclusions that "the electrolytic theory of the corrosion of iron is untenable" upon the alleged fact that iron will not corrode in the presence of water and oxygen so long as carbon di-oxide be absent, but that in the presence of water and oxygen and the most minute trace of carbon di-oxide the solution of the iron with subsequent further oxidation and the formation of rust takes place. In the crucial experiments of Mr. Friend, the iron under observation was first washed with caustic soda, and the assumption made that several rinsings with pure water are all that is necessary to remove this caustic soda. We have shown, by conductivity experiments, that caustic soda is held by the iron most tenaciously. It is worthy of note that the one experiment in which rusting always took place in spite of every precaution to exclude carbonic acid, was the one in which the iron had not been soaked in

caustic soda previous to its exposure. Assuming, but not admitting, that the experiments of Mr. Friend satisfactorily show that the above conclusions are true, this fact would not in the slightest way contradict or even open to question the electrolytic theory of corrosion, but would, on the other hand, substantiate it. It is conceivable, though I do not think possible, that the hydrogen concentration which obtains in pure water may not be sufficient to produce an osmotic pressure of hydrogen which in connection with the solution pressure of the iron will set up an electromotive force sufficient to cause an appreciable electric current to be generated and flow between two separate points on the surface of the iron; and that it requires just this increase in the concentration of the hydrogen ions which is occasioned by the introduction of this small amount of carbon di-oxide in the form of carbonic acid, to produce an electro-motive force sufficient to cause such an appreciable current to flow and to thus produce the observed solution of the iron and in the presence of the oxygen, rusting. But it will be clear, that by the electrolytic theory of corrosion, we are able to explain these results more consistently than can be done by any other theory of corrosion yet suggested. In fact there is no explanation for the influence of carbonic di-oxide on corrosion other than the fact that it is an acid; this in turn assumes an accelerated action due to an increase in the concentration of the hydrogen ions, and we are forced to the electrolytic theory for a satisfactory explanation of the action in the end.

One fact regarding the corrosion of iron appears to be undisputed, viz., that oxygen is necessary for a continued action. This corrosive action can cease from two causes, viz., the osmotic pressure of the dissolved iron may increase until it neutralizes or compensates the solution pressure of the metallic iron; or the action may be stopped by the separation of a film of molecular or gaseous hydrogen upon the metal, which, owing to its resistance, prevents the flow of an appreciable current. From the fact that iron possesses even in relatively concentrated solutions of iron salts, a very appreciable potential, it would seem highly improbable that the solution of the iron in water should

have been stopped by the osmotic pressure of that already dissolved, and therefore, although the oxidation and subsequent precipitation of the already dissolved iron is the *most striking* function of the oxygen, it is probably by far the least important and its real accelerating action lies in the destruction of the hydrogen film already separated out on the surface of the metallic iron.

That this is true, may be seen by the consideration of a number of now well-known phenomena. When a piece of iron is placed in ordinary water, exposed to the air, it will dissolve or corrode or rust. If now there be placed in the water with this piece of iron, a piece of platinum, the solvent or corroding action of the water will not be changed. The oxygen is present in the solution as before, and the iron ions as they separate from the metallic iron are being oxidized and precipitated as rust. If now the platinum and iron be electrically connected, a marked increase in the rate of the solution or corrosion of the iron is noticed. No chemical condition has been changed; the difference lies in the fact that there is now an electrical contact between the iron surface and the platinum, and the platinum furnishes a surface on which the hydrogen can deposit and on which, by virtue of its catalyzing action, the hydrogen will be rapidly oxidized by the dissolved oxygen and thus removed from the sphere of action. Or if in two limbs of a U tube, separated at the bottom by a jelly plug, there be placed two pieces of the same iron, electrically connected, and in a very dilute solution of any electrolyte, and both of these limbs be protected from the air, no action will be noticed. That is; there will be on both pieces of iron, points at which iron has gone or tends to go into solution, and points at which a film of hydrogen has deposited, and, owing to the resistance of this film of hydrogen, no local currents pass over the surface of the pieces of iron and no current as a whole passes through the jelly plug at the bottom, or through the system as a whole. If now, there be placed in one of the limbs, a substance which will unite with hydrogen, such as potassium bi-chromate or alkaline hydroxylamine, still no action will be observed in that limb, but the iron in the other limb will pass into solution and a current of electricity will pass through the system.

A third example is found in the action of zinc in water containing an electrolyte. If a strip of zinc and a strip of iron be placed in water containing a very little salt, the iron will corrode rapidly while the zinc will not be noticeably attacked. The usual explanation for this phenomenon, is, that the zinc protects itself with an adherent film of zinc oxide or hydroxide, while the iron produces a non-adherent voluminous hydroxide which does not protect. If, instead of being separated, the two strips of metal be placed so as to touch each other, the iron no longer corrodes, but the zinc very rapidly passes into solution. The presence of the iron cannot affect the nature of the coating of zinc hydroxide, which, in the previous case, adhered thereto and protected, according to the old explanation, the sheet of zinc; nor can the presence of the zinc affect the oxidation and precipitation of the iron ions should they pass into solution as they are wont to do. The explanation consistent with the electrolytic theory is, that the zinc in the first arrangement does not dissolve and corrode, not because there was formed an adherent and protecting layer of zinc hydroxide, but because the surface of the zinc does not catalyze the reaction $\text{H}_2 + \text{O} = \text{H}_2\text{O}$ with sufficient rapidity to continually remove the hydrogen from the surface of the zinc. The film of hydrogen, therefore, forms on the zinc and protects it, and it is said to be "polarized." Although the catalyzing action of the iron surface is not so rapid as is the platinum surface, it has sufficient rapidity to depolarize the iron strip and to render continuous the solution, and therefore the corrosion of the iron. While the solution pressure, that is, the tendency to pass into solution, is much stronger in the case of the zinc than it is in the iron, the iron corrodes and the zinc does not, because the electrolytic double layer set up on the surface of the zinc cannot be destroyed by a flow of electric current. When the two are united, the greater solution pressure of the zinc forces a larger number of zinc ions into the solution than does the iron force iron ions into the solution, and the net result of the flow of current is that the zinc soon becomes anodic over its entire surface, while the iron becomes the cathode, and that no iron is then dissolved, but as

a cathode furnishes a surface on which the hydrogen set free by the solution of the zinc may be deposited, catalyzed and removed.

It has been shown by Richard and Lonnes * that when an electric current, at low current density, is passed through water in the presence of air, that hydrogen is not liberated at the cathode as a gas, but that it unites with the dissolved oxygen at the electrode forming first hydrogen peroxide, and then water. Since identically these conditions obtain in the corrosion of metals, this same phenomena doubtless takes place; in fact, Dunston † was able to identify the presence of hydrogen peroxide in the products of the corrosion of zinc, although no direct proof of its existence on the surface of corroding iron could be obtained.

I have already shown that "mill scale" or magnetic oxide of iron is strongly electronegative to iron. Since mill scale is insoluble in water and cannot of itself enter into the reaction, its only function can be analogous to that of platinum or other insoluble conductor of this kind, viz., to furnish a surface on which the hydrogen liberated by the dissolving iron can separate and be catalytically oxidized to water again. This is also true of the black oxide protective coatings, sometimes used upon iron and steel, as for example, that of the Bower-Barf process. Just as is the case in mill scale, these coatings are very serviceable so long as the whole coating is intact. But so soon as a portion of the metallic iron is exposed, this portion corrodes all the more rapidly on account of the presence of the surface of scale on which the oxidation of the hydrogen and consequent depolarization can go on. The inevitable result is that a "pit" forms at the exposed point and grows deeper and more marked in proportion, as the scale is dense and closely adherent to the iron surface. Hence, if it were possible to remove the mill scale entirely from steam boiler tubes, for example, pitting would be largely eliminated, and the life of the tube prolonged. The influence of the presence of mill scale on iron may be seen from the following experiment: Two pieces of iron were cut from a bar which was coated with the original rolling mill scale. On one of the pieces parallel strips of

* Z. Phys. Chem., 20, 145.

† Chem. Soc. (London), 84, 1584.

fresh iron were exposed, leaving alternate strips of the scale. The other piece was planed free from scale. Both were exposed to corrosion in water for one week and the loss in grams was, for the average of a large number of tests:

Plain Steel
0.560 gram.

Steel and Scale
0.860 gram.

The well-known fact that zinc in electrical contact with iron will protect the latter from corrosion, has already been spoken of. Although this statement is universally made in text books, the fact that in consequence of the protecting action to the iron, the zinc itself will rapidly be dissolved is not mentioned. Both actions will be the more complete, the more energetic is the solution of the zinc and the correspondingly greater flow of current from the zinc to the iron. But the flow of current will depend, among other things, upon the resistance offered to its passage through the water. Hence it should be possible to get water so pure, or to place the iron so far from the zinc that the electromotive force of the system could not overcome the resistance and no appreciable current would flow, and the iron should corrode as though no zinc were attached to it. It was found that Boston water, as drawn from a tap in the laboratory, had a sufficiently low conductivity, so that zinc attached to a piece of sheet steel would protect it when placed in the water for only a distance of three-fourths of an inch. When a little common salt was added to the water, the protection was extended for a foot and one-half or more. Hence in order that zinc may protect iron from corrosion it is necessary to have present in the water surrounding the two, enough electrolyte to insure a low resistance to the flow of the current generated by the solution of the zinc.

The fact that the presence of a metallic iron surface accelerates the corrosion of zinc, has an important bearing upon the protection of such structure as barbed wire fencing, or, whenever both an iron and zinc surface are exposed. In making barbed wire fencing, the wire is first galvanized, and when wound into fencing, the cross wires forming the barbs being cut at an angle in order to make a pointed barb. This freshly cut surface of iron is thus exposed, and so furnishes just the

surface required for depolarizing the zinc surface and thus greatly increasing the rapidity with which the zinc coating will corrode. As the zinc coating thus recedes from the iron surface the latter rusts on account of the low conductivity of the water film on the two, and hence the explanation of why deterioration of a barbed wire fence always starts at the barbs and travels from there along the strands.

It would seem worth while in this connection to pass the finished barbed wire through a wet galvanizing bath in which the wire should be cathode, and be surrounded by a zinc anode so that the current would be attracted to the barbs, and hence the zinc deposited almost exclusively on just the points where it is needed. Little if any would be plated on the wire strands.

In examining barbed wire fencing which has been exposed for two or three years it is not infrequently found that one of the two main unit wires making up a strand will have corroded much faster than the other which is close along side of it, and in direct contact with it. Three factors may enter into this difference. First, the steel may itself be inferior in one wire; second, the zinc coating may be thinner, i. e., "wiped" closer on one than on the other; and third, the zinc coating may be contaminated with a zinc iron alloy. While the first two are matters understood by the wire makers, the third is not so easily detected. The alloy, known as "hard dross" by the galvanizers, and which, owing to its high melting point, settles to the bottom of the galvanizing pot, contains from 4 to 6 per cent. of iron. This is in reality a mixture of the alloy, iron and zinc, and while the properties of zinc still predominate, the effect of the presence of the alloy may be easily detected. Contrary to what might be expected, the iron zinc alloy, is *electro negative* to iron; that is, it will act like platinum or mill scale and accelerate the depolarization of the cathodic (hydrogen) surface, and thus aid corrosion. This alloy and its behavior towards oxidation will form the subject of a future paper, but its influence on the ease with which hydrogen may be liberated from a zinc surface may be seen from the following experiment:

Alloys of iron and zinc were prepared and pieces of a uniform size placed in 2 per cent, H_2SO_4 for $\frac{1}{2}$ an hour. The loss of weight was determined and is given in grams loss per minute per sq. in. exposed area :

Percentage of Iron in Zinc	Total Loss in Weight	Loss per Minute
0.60	0.240 gram.	.0040
1.20	0.384	.0062
1.90	0.504	.0084
2.66	0.658	.0109
3.35	0.694	.0115
3.80	0.742	.0123
4.40	0.852	.0142
4.90	0.888	.0148
5.50	0.925	.0154
7.	0.971	.0161
	1.074	.0179

The concentration of the hydrogen ion in such a case as this is so widely different from that which exists in water, as we ordinarily find it, and oxygen plays so negligible a part in this acid solution compared with ordinary corrosion, that I think a comparison here of doubtful value, but the table shows the direction which the effect produced by the presence of such an alloy would take.

Since corrosion depends upon the depolarizing effect of oxygen, any reagent which would exclude oxygen from water should retard corrosion. It has been shown that the solubility of oxygen in a solution of common salt decreases as the content of salt increases. Hence the corrosion of iron should be universally proportional to the concentration of the salt solution. In the following table is given the loss of iron in grams per square inch exposed area, of some steel plates exposed alone, and the loss of both steel and zinc plates where the two were in contact :

IRON IN WATER CONTAINING SALT

Water Contains Sodium Chloride	1 Week's Exposure	2½ Week's Exposure
25 grams per litre	.0786	.175
50 "	.0698	.150
100 "	.0614	.132
150 "	.0454	.101
250 "	.0341	.065
300 "	.0180	.057
	.0068	.045

IRON AND ZINC IN CONTACT

H ₂ O	Fe	Zn
10	.032	.097
25	.0004	.170
50	.0007	.163
100	.0005	.154
150	—	.130
250	—	.087
300	—	.062
		.068

A common type of corrosion of iron which is generally considered as a subject by itself, is the corrosion of tubes and shells of steam boilers. The function of the oxygen (with which the normal feed water of a boiler is saturated), is here the same as in other types of corrosion, and as boiler tubes cannot be protected by paints or other coatings the detrimental effect of the oxygen must be counteracted in some other way.

If the feed water used be perfectly free from dissolved salts there is lacking in the boiler that protective coating of scale which, while it reduces the heating efficiency of the boiler, also protects the iron of the boiler from the access of oxygen. In such a case, it is well to feed into the boiler, when first put into commission, enough water containing scale-forming salts to thoroughly coat the shell and tubes with a layer of hard boiler scale. This practice is very common in marine boilers which are to be fed with distilled water. Although, as we have seen, the presence of alkalies inhibit the corrosion of iron by reducing the hydrogen concentration, and although, as Dr. A. S. Cushman has shown, the presence of bi-chromates in solution greatly inhibits this action, the best practice is to remove oxygen from the feed water before it is introduced into the boiler, just as it is the best practice to remove the scale forming salts of the ordinary feed water before this is used.

As the solubility of oxygen in water rapidly decreases with rise in temperature, by far the larger portion of the oxygen dissolved in natural waters, or in distilled water, is removed by heating the water to near its boiling point. If in addition to the application of heat, a vacuum be maintained over the water, the dissolved oxygen is practically all removed, and such feed water will never corrode the boiler. Such an

arrangement has been in use in a few of our largest steam generating plants with the greatest success. Even if no diminished pressure can be maintained over the hot feed water, the mere heating to the boiling point will drive out most of the dissolved oxygen. If therefore an open feed-water heater be employed, the feed water is deprived of its oxygen without additional expense for the heat, because the feed water in any case must be brought to its boiling point the moment it gets within the boiler. This method of treating boiler feed water has also been found very efficient in the power stations of one of our large electric railway companies.

A third method of depriving the feed water of its oxygen is to carry the same through a tank filled with small pieces of scrap iron. The accumulated iron hydroxide must of course be cleaned out of the tank periodically and the scrap iron renewed. But from the point of economy, it is of course much cheaper to pit and corrode scrap iron in a tank, than it is the tubes inside the boiler, so that this method, especially if combined with an open feed water pre-heater, is in the end a very economical and highly efficient one.

If for any reason, it is not possible to remove the oxygen from the water before it is fed into the boiler, numberless boiler compounds are available to counteract the effect of the oxygen within the boiler. Such a method is of course irrational, and is nothing more than voluntarily taking poison with the expectation and intention of taking at the same time an antidote therefor. The compounds and mixtures which have been proposed for introduction into a boiler includes practically every thinkable material extant. The basis of most of them, however, is sodium carbonate in the form of soda-ash, and are effective only in so far as they reduce the hydrogen concentration in the water. A considerable portion of the soda added is frequently consumed in precipitating the scale forming salts of the water, and is, as a rule, of low efficiency as an anti-corroding ingredient. In as much as an alkaline solution of the ordinary tannins or tannin extracts break up more or less when subjected to the heat and pressure of a steam boiler, into

gallic and pyrogallie acids, which are energetic absorbents of oxygen, a solution of this material is efficient as a boiler compound for preventing corrosion.

A very old method is of course the introduction of pieces of metallic zinc into the boiler, which operate in accordance with the principles already discussed. It is necessary, however, to maintain good electrical contact with the iron and to have in the water sufficient electrolyte of some sort to carry the current from the zinc to the iron. For the protection of condenser jackets using sea water, this method has been found to be perfectly satisfactory and entirely trustworthy.

Research Laboratory of Applied Chemistry, Mass. Inst. of Technology.
October, 1908.

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 - ✓ 13—Protective Coatings for Iron and Steel. *By Robert S. Perry.* (In press.)
 - ✓ 14—Coatings for the Conservation of Structural Material. (In press.)

Protective Coatings for Steel and Iron

WITH DISCUSSION

By **ROBERT S. PERRY**

*Read and Discussed Before the
AMERICAN CHEMICAL SOCIETY
PITTSBURG, PA.
February 18th, 1909*



Scientific Section
Paint Manufacturers' Association
3500 GRAYS FERRY ROAD
PHILADELPHIA, PA.

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PROTECTIVE COATINGS FOR STEEL AND IRON

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CHAPTER I.

It is of extreme importance that the engineer, who practices his profession in a city where large quantities of steel are produced under his supervision, should have more than a superficial knowledge of the subject of protective coatings.

That the engineer or chemist who is investigating the characteristics and properties of steel should follow up the investigations on the subject of paint is very clear, and the object of this paper is to bring the two subjects into close touch and give a general outline of the most recent work thereon.

Relation of the
Engineer to the
Conservation of
Steel and Iron

One of the most vital problems of the present day that is presented to the American public is the conservation of our natural resources. Probably the most important product that comes under this heading is the prevention of the decay of the iron and steel that plays such an important place in modern industrial activity. The metallurgist should give his best brains and tireless energy to the solution of this problem and work in direct co-operation with the Paint Scientist to produce permanence of material, and at the same time maintain, wherever possible, the decorative and artistic.

State and nation should aid in this work by appropriations for its continuance, under the skilled guidance of those pioneer investigators who have already worked so hard to develop scientific laws, the observance of which tend toward the economy of material.

National and
State Aid in
Investigation

The various grades and varieties of steel products, which are being manufactured in our steel districts and which are shipped all over the world, have been shown to exhibit a variance in the rate and manner of corrosion. A study of the causes of this action has located in certain cases the factors which govern this corrosion, and upon this work depends the furtherance of the industry. It has been found necessary of late in the paint industry to develop and place it on a higher plane, and this has been

Development of
Work by
Metallurgist
and Paint
Scientist

accomplished largely through the light of scientific investigations. The knowledge placed at the disposal of the manufacturers of the country by the investigations of the Scientific Section and by independent investigators in the field of paint technology, enables the manufacturers to produce, when they so desire, products far superior to those of the past.

We read that Noah finished off the ark by painting it "within and without," while the solution of man's first technical problem and his first industrial effort found expression in Adam and Eve's first protective coating of fig-leaves and skins—decorative, perhaps, but, compared to the protective coatings of to-day, somewhat deficient in the requisite qualities of durability—of impenetrability, or excluding power—and in hiding or covering values.

We learn now, with humility, that we have been, in the past, incorporating in many so-called protective coatings—or paints—certain pigments, which, instead of preserving, do actually attack the iron structure beneath. Like poison ivy among Adam's leaves, these can, where present, be held responsible for resulting trouble.

The manufacturer, the master painter and the property owner are all interested to-day, as never before, in the subject of paint.

The progressive paint manufacturer is making great effort to put the art of paint manufacture, as far as possible, under the control of exact science.

The property owner desires further knowledge of this subject, in order that his property may be protected for as long a period as possible when he invests his money in a coating of paint.

Both, the master painter and the engineer or property owner, to-day clearly appreciate the fact that the total cost of the paint itself is only from one-third to one-fourth of the cost of the final protective coating, including labor and material, and that too much care cannot be taken in choosing the material, because the other three-fourths of the investment, namely, the labor cost, may be

Property Owner
Equally
Desirous
of Data

Comparative
Cost of
Material and
Labor in a
Paint Job

rendered valueless by the use of an adulterated paint or one prepared after a poorly balanced formula.

Let us first consider the service which a paint has to perform when applied as a protective coating. In discussing the conditions, it is proper to take the most severe service and that for which paint is most largely used. We will, therefore, confine ourselves to paint used out of doors to protect iron in the form of structural material.

The average paint coating is only three one-thousandths of an inch thick, and yet this thin coating is required to withstand expansion and contraction of the underlying surface, abrasion or wear from storms, of dust and sand; or rain, sleet and hail. It must have both hardness to withstand to a reasonable extent this surface wear, and yet enough elasticity to meet internal strain and to conform to changes in the underlying surface, and it must penetrate and cling to the surface upon which it is applied. It must also retard or prevent from access to the underlying surface; both the moisture and atmospheric gases which cause decay.

Let us consider the nature of the materials upon which the paint is to be applied.

The chief agency to decay is moisture, whether the moisture is brought to the surface through the gases of the air or in actual visible form, that is, as liquid water.

Human experience has thus far found a paint coating the best barrier to exclude these agencies of decay, liquid water and the gases of the air. Paint to produce this coating is usually composed of linseed oil, a semi-liquid known as the vehicle, containing necessary thinners and driers, and small particles of solid matter suspended in the oil, known as the pigment.

The painter spreads this paint as a thin film under his brush, and this film, by the action of the oxygen in the air, hardens into a coating composed of semi-solid linseed oil or dried linseed oil containing the small particles of pigment.

This paint coating of linseed oil and pigment has re-

Service
Required
of a Paint

What a
Paint Coating
Does

Cause of
Decay of
Lumber

Paint,
the Great
Arrester of
Decay

Elasticity and
Hardness of
Surface
Necessary in a
Paint Coating

markable elasticity, so that it will conform to shrinkage or swelling of the underlying material and will adapt itself to strains within the mass of the actual coating itself, and to exterior or outside physical violence, while the pigments give to this soft and otherwise rather perishable linoxyn the indispensable properties of solid matter necessary to preserve the life of the paint coating.

It is well that we should go to school to living nature to ascertain what provisions she has made to protect the life of living structure.

Living Nature
Furnishes Her
Own Protective
Coatings

When a tree is injured, the life-blood, or circulating fluid, in the form of sap, immediately pours out to protect the wound.

This vegetable fluid, or sap, forms a thin film over the wound, just as the painter spreads his coating of oil over the dead lumber, and then, by the action of the air, this semi-liquid sap is hardened to a semi-solid film, or gum, which is startlingly like the coat of linoxyn.

The tree is endowed with life and can, by gradual growth, repair the wound thus temporarily closed. Therefore, the paint coating of living nature need not be very durable. Structural material, on the other hand, requires a more durable protection, and both the master painter and the property owner desire a maximum life for the coating of paint, so that they may obtain the greatest value from the investment of their time and money.

Analogy
Between
Sap and
Linseed Oil
as Preventives
of Decay

We have thus seen that human experience has unconsciously gone to linseed oil, itself originally the vegetable sap, or life-blood, of a living structure, and that human ingenuity has thus copied nature in producing the coating of linoxyn.

The linoxyn, or dried oil, alone is seen to be porous, soft and perishable.

Necessity for
Pigments

Human experience has sought to meet the second problem, that of permanency, by the addition of particles of pigment to the body of the paint, to give greater solidity, durability and to sufficiently fill the pores or voids.

CHAPTER II.

THE LAW OF MINIMUM VOIDS WITH THE USE OF PIGMENTS CONTAINING PARTICLES OF PARTICULAR OR DETERMINATE SIZES.

A careful consideration of the combination of solid material with a semi-fluid vehicle, shows that in many respects the problems are identical with the problems involved in the preparation of concrete.

The Analogy
of Coatings
to Concrete

Just as with concrete, the problem is to produce strength with the minimum of voids by using a mixture of particles of three or more determinate or characteristic sizes, just so, in the coating of paint, a minimum of voids and a maximum of imperviousness can be obtained by a wise selection of three proper materials which supply these three different determinate or characteristic sizes of particles. This proposition was stated as a matter of scientific deduction, by the writer, in 1906, in papers read before the American Society for Testing Materials, and also before the Detroit Chapter of the American Institute of Architects.

The Law of
"Minimum
Voids"

To-day it is possible to prove and confirm this law by a simple yet striking experiment.

We can first demonstrate that a film of dried vegetable sap or oil, such as linseed oil, which the chemist calls linoxyn, is filled with what the cement expert calls "voids" and is porous, and the following table will show the rapidity with which carbonic acid gas actually passes through such films of linoxyn with various pigments incorporated or ground into the oil. Taking the porosity of a film of oil and asbestine as 100%, we find as follows:

Porosity of a
Coating of
Linoxyn

Asbestine 100.00%

Corroded white lead 89.10%

A high grade scientific paint, containing

white lead, asbestine, and zinc oxide ... 71.00%

on two hours' treatment.

Test for
Relative
Porosity of
Various Paint
Coatings

Now, let a number of films of linoxyn be prepared, the first containing, say, one pigment, such as barytes, another containing two pigments, such as barytes and blanc fixe, and a third film, carrying three pigments of different sized particles, for instance, barytes, blanc fixe and zinc oxide; let these films be used as covers or seals for as many glass receptacles.

It will be noted that the barytes has the coarse particle characteristic of a natural mineral, and that the precipitated blanc fixe has a smaller but characteristic size of particle, resulting from its precipitation from solution, while the zinc oxide has an infinitely fine size of particle, due to its formation from a fume, a particle size so fine that while passing over as a fume from the furnace to the solid form, it shows characteristics of gas tension.

Let us place in these glass receptacles, previous to sealing, a reagent or chemical which will absorb carbonic acid gas and fix it chemically in such a way that we can measure or weigh it. Ordinary lime water which can be purchased in any drug store will do this, and will form with the carbonic gas, calcium carbonate, or common whiting; or we can substitute color indicators sensitive to carbon dioxide. If these receptacles be now placed in a tight room or container filled with carbonic acid gas at somewhat above atmospheric pressure and so that the gas is pressing equally on each skin, it is evident that we can measure the relative porosity or sponginess of each film by the amount of gas which it allows to pass through from the outside into the container which it seals. Thus we obtain a comparative measure of the effectiveness of any pigment or group of pigments taken to close the pores or voids which have been mentioned as existing naturally in the linoxyn itself. The average results obtained from a number of such experiments show that beyond all question pure linoxyn without pigments is extremely porous. It is also shown that a paint must have pigments in it; that one pigment does part of the work of filling the voids; that two do more of the work; but that if three or more pigments of different sized particles are used to

Minimum
Porosity
with Minimum
Voids

make the paint, we get much better excluding values, and go a great step forward in making the paint skin sufficiently impervious to gas. Similar experiments yield similar results with regard to moisture.

It has thus been shown that it is necessary to use a fluid or vehicle for producing the coating and one which will give accommodating elasticity.

It has been further shown that it is necessary to use pigments to render the paint coating more impenetrable to gases, moisture and other agencies of decay, by the use of pigments or particles of three or more characteristic or different determinate sizes.

Many of the problems involved in the art of making paint are yet to be solved. If one valuable pigment be used as the base of the paint, its size of particle and its physical characteristics will cause the efficient manufacturer to choose those other particular pigments which will properly balance the valuable base pigment so chosen, but the exact proportions to give the minimum of void with the maximum of oil elasticity is not yet a precise science, and we must for the present be guided in this by the ripe experience of the conscientious manufacturer.

If we take paint films composed of various pigments and test them with the Perry Film Testing Apparatus, which gives an approximate measurement of the elastic limit or limit at which a paint skin, composed of linoxyn and the pigment, will break, we get data which shows that white lead or similar pigments should be largely used to preserve or rather to avoid depletion of the elasticity of the linoxyn; the experiment also shows that zinc oxide or similar material with extremely fine particles should be used in fairly liberal proportion to fill the pores, but that excessive use of a pigment of this kind will destroy the proper elasticity of the film and produce cracking and peeling.

We also find that asbestine, or similar materials with needle-like structure, used in moderate proportion, add wonderfully to the strength of the paint coating. Thus the result of human experience in compounding high grade

Elasticity from
the Linoxyn

Density from a
Mixture of
Pigments

Proper Use of
Different Sizes
of Pigments

Testing
Apparatus to
Determine
Elasticity of
Various
Coatings and
Formulas

Reinforcement
of Coating with
Asbestine

paints is confirmed by the apparatus which measures the porosity of the paint, and again by the apparatus which measures the elasticity and strength of the film.

CHAPTER III.

PROTECTIVE COATINGS THAT EXCLUDE DECAY VS. THOSE WHICH BOTH EXCLUDE AND INHIBIT DECAY.

The past forty years measures a very great advance in the production of paints for paint coatings to exclude moisture and gases, the agencies of decay.

The forty years have produced some high-class paints which to-day give a minimum of pores or void spaces and a maximum of constant impenetrability and of exclusion to agencies of decay, greatly accommodating elasticity from the linoxyn, so that the paint coating accommodates itself to the expansion and contraction of the structural material upon which it is applied, in short, the art up to date has produced coatings which are very good "EXCLUDERS" or good water-proofs for the structural material to be protected.

Up to the year 1906, however, neither the paint manufacturer nor the consumer questioned much if any whether the materials used were beneficial or harmful to the structural material upon which they were applied.

Up to 1906, the manufacturer paid great attention to the problem of preventing internal chemical action or chemical change within the body of the paint coating itself, but it never seemed to have occurred to him or to the consuming public that in the excellent excluder or water-proof coating, the materials themselves would perhaps have chemical or other action upon the surface of the *structure* to be protected.

It may be of interest to compare the present situation in the science of protective coatings with the situation in medical science at the time when Pasteur fought his battle for antiseptics during the period following the Franco-Prussian War. At that time medical science treated wounds by cleansing the surface and bandaging.

Efficiency of
Paints as
Excluders of
Decay Agencies

Choice of
Materials for
"Excluders"
Disregarded
their Action on
Structural
Surface

Analogy of
Excluding
Paints to the
Excluding
Bandages
of Surgery
Prior to Pasteur

Excluding
Paints Should
also be
Inhibitive or
Antiseptic

Pasteur first insisted that antiseptic treatment and antiseptic bandages must be used.

The development of protective coatings has given us excellent bandages or excluding coatings, which, like the old surgeon's bandages, have been primarily constructed with a view to *excluding* the agencies of decay.

The new discoveries and the new science do not ask that we rob our paint coating of any of the qualities of strength, durability or imperviousness which we have attained to while developing these materials as *excluders*, but, while maintaining all these values, we must eliminate any pigment which would be harmful to the surface which the paint is intended to protect, and at the same time add those materials which, without injuring any of the other qualities of the paint, will tend to inhibit decay.

The new science has made rapid strides in the past two years in furnishing data relative to the cause of corrosion of iron and steel and of the action on iron or steel of the various materials used in the paint industry. Similar work on cellular tissue presents grave difficulties which have rendered our advance much slower and we will not deal at this time in the possible inhibition of the decay of organic structural material, leather, etc.

CHAPTER IV.

THE INHIBITION OF THE CORROSION OF STEEL AND IRON AS STRUCTURAL MATERIALS.

The direct relation of the materials used in paint, to the corrosion of steel and iron, and the extent to which they might stimulate decay, seems never to have been investigated. Also, the possibility that ingredients might be used which would act as antiseptics or inhibit the corrosion of iron and steel, seems to have occurred neither to the manufacturer nor to the public. The researches of Dr. Allerton S. Cushman, of Dr. William H. Walker, and of other scientists, equally well known, have during the past two years awakened both the manufacturer and the public to this problem, and it has been clearly demonstrated that there is an important and measurable difference between the behavior of various materials used in the paint business, and that some of them conserve while others tend to destroy the underlying structure.

Turning, therefore, to the conservation of structural iron and steel, and to its rust inhibition through particular coatings, we have the problem of choosing the proper materials for manufacturing a paint which will both exclude the agencies of rusting, and which, when moisture and gases do penetrate the coating, will inhibit the iron from rusting; and we also have the problem of giving to the chemist, engineer and architect some simple method of determining whether any given paint is, in at least rough measure, harmful, safe or beneficial.

In the case of structural steel we have a condition of the surface to be protected, essentially different from the conditions existing with lumber.

Lumber, no matter how well kiln dried, invariably has some moisture in its structure.

It has been absolutely demonstrated, and all technical

Preservation of
Steel and
Iron

Permeable
Nature of
Oil Film

men acquainted with the subject are agreed, that linseed oil, when dried to a coat of linoxyn, has voids or pores in it.

The paint manufacturer uses a combination of pigments which largely fill these voids, but the most carefully prepared coat of paint for lumber, when the vehicle is linseed oil, without the addition of varnish, is always somewhat porous, and the moisture has some opportunity to pass out without blistering, etc.

Structural Steel
Requires a
Non-Porous
Film

In the case of structural steel we have no moisture in the structural material to contend with, as we have with lumber, and, therefore, we can safely add varnish gums in solution to the linseed oil, thus producing a more nearly water-proof coat to the agencies of decay.

Varnish Gums,
in Oil,
Reduce
Porosity

The action of the gum, diffused throughout the linseed oil by solution, is to help to fill up or fuse together the pores or voids, or, in other words, to render the linoxyn film more resistant to the entrance of moisture and prevent the passage of moisture through the paint coating to the structural material.

Anti-Rust
Paints
Improved by
Gums in
in Vehicle

This is the conclusion reached from the standpoint of technical research, and practical experience has also demonstrated that those coatings which have been proved the best protection for steel, have invariably contained a vehicle in which some gum or varnish material has been present.

It is a fairly safe generalization that the vehicle should thus be so modified as to produce a more fluid and less porous coating for structural steel and iron, while at the same time the paint must be most carefully compounded, so far as the solid pigments are concerned, to give a minimum of voids and a maximum of strength and of durability.

Necessity for a
Blend of
Pigments to
Fill Voids

If the conditions which give physical strength and durability have been observed, the one other precaution which is necessary is to avoid the use of any pigment which would be chemically active, either with regard to the vehicle or with regard to the structural steel and iron.

A number of the pigments which are used in the paint

industry, unfortunately, react with the linseed oil and tend to produce internal disintegration of the coat, as, for instance, white lead.

Other pigments largely used in the paint industry, and of value in a paint for protecting lumber, are unjustifiable in a paint for the protection of steel and iron.

For example, sulphate of calcium, which, even if fully hydrated, has been shown to have a direct stimulative action upon steel.

This is due to the fact that calcium sulphate, even if fully hydrated, is somewhat soluble in water, and when the water penetrates the coating of paint it carries this calcium sulphate into solution.

Due to the fact that calcium sulphate, in solution, has a high co-efficient of dissociation (or, in other words, has a tendency, in solution, to break up from its chemical form and identity), we get the reaction of the liberated sulphuric acid ions upon iron and steel, causing corrosion.

The highest type of paint products for the protection of iron and steel, therefore, avoid the use of such pigments as calcium sulphate.

Great caution must be used in selecting iron oxides for the protection of iron and steel, as they often carry traces of sulphates, etc., as impurities.

Venetian red, which is a favorite pigment, and which is of value for protecting lumber, is made by calcining green vitriol or sulphate of iron (commonly called copperas) in the ferrous form, in the presence of quick lime. The resulting mass from the furnace consists of artificial oxide of iron and sulphate of calcium, produced by the metathesis of the above reacting compounds.

Unfortunately, the reaction is never complete, and there is a tendency towards the formation of free sulphuric acid.

As a result, we have all the bad effects with Venetian red that we find in the use of calcium sulphate, and also the extra chance of corrosion due to free and aggressive sulphuric acid present.

It is true that there are some *artificial* oxides of iron

Caution
Regarding
Pigments
Chemically
Active with
Oil

Caution
Regarding
Pigments that
Corrode Steel

Caution
Regarding
Calcium
Sulphate

Caution
Regarding
Venetian
Red

Caution
Regarding
Artificial
Oxides of Iron

which can with safety be used, as, for instance, artificial black magnetic oxide produced by chemical precipitation, but, as a general proposition, the *natural* iron oxides should be used, unless it is absolutely certain that the artificial oxide has been proven safe.

Ochres

Ochres are not meant to be included in the safe class in the above statements, for the reason that ochre is an extremely impure oxide of iron.

Grouping of
Pigments into
Inhibitors
Inerts
Stimulators

Recent investigations into the nature of pigments have revealed the fact that they may be divided into three groups and termed Rust-Inhibitives, Inerts or Rust-Stimulators. The nature of the pigment itself, or the nature of the impurities contained within the pigment, are factors deciding the position of the pigment in one of the three groups or types above mentioned. It may be expected that the use of rust-inhibitive pigments in paints designed for the protection of steel surfaces will give to such a paint very valuable properties. Further consideration of the subject will aid us in selecting the proper pigments for such a purpose.

According to the electrolytic theory of corrosion, certain fundamental principles underlie the corrosion of iron.

They are, briefly, as follows:

Electrolytic
Theory of
Corrosion

That, when iron is in contact with water, there will be a transfer of electricity from the free hydrogen ions of the water to the iron ions of the iron, causing the solution and subsequent oxidation of the metal.

We are indebted to Dr. William H. Walker for the most recent research on the function of oxygen in the corrosion of iron:

"That the film of hydrogen thus deposited on the metallic iron at the beginning of the action is a non-conductor of electricity and prevents further passage of the current, and hence, further solution of the iron. Atmospheric oxygen removes the film of hydrogen by combining with it, thus 'depolarizing' the iron and allowing the solution of the iron to proceed. When once in solution in water, this dissolved iron is also oxidized by the atmospheric oxygen and precipitated as rust; but this

oxidation is incidental to, rather than a necessary condition of, corrosion.

“That when iron is in contact with any surface on which this combination of the hydrogen, set free from the water, and oxygen, from the air, will take place more easily than on the iron itself, such as copper, bronze, mill-scale, etc., corrosion of the iron will be accelerated thereby.”

The presence of impurities having a difference in potential to that of the iron in which they are contained, and the uneven distribution of such impurities, increases the amount of electrical action.

Certain compounds are of such a nature as to excite electrical action, and, consequently, stimulate corrosion, while still other compounds are of such a nature as to inhibit or prevent corrosion.

To the class of compounds that inhibit corrosion belong bi-chromates of the alkaline earth metals, these salts being pre-eminent among such compounds. It has been found that salts of certain metals may be precipitated with the chrome salts to produce pigments which afford protection for the steel surfaces to which they are applied.

The results of a series of investigations into the rust preventive nature of these compounds demonstrated that it was not safe to state that the chromates, as a class, were rust-inhibitives. Quite the reverse is true of many of these products and their composition, method of preparation, and impurities are factors which influence, to a marked degree, their value as protective compounds. Aside from those chromates which prevent corrosion, we have those which act in an inert manner, also those in which any inhibitive value is overbalanced by the effect of impurities, showing a strong stimulating action in the rusting of metal. But a simple test will show in which class the chromates come.

Value of
Chromate
Pigments
as Rust
Inhibitors

CHAPTER V.

THE STEEL TEST FENCES TO CONFIRM SCIENTIFIC INVESTIGATION OF RUST INHIBITIVES.

Steel Test Fence

In order to ascertain the rust-inhibitive value of all pigments, the Scientific Section was commissioned by the Bureau of Promotion and Development of the Paint Manufacturers' Association to erect a fence, having several hundred steel plates, upon which to try out the value of the different pigments when contained in an oil medium.

The American Society for Testing Materials was informed of the work proposed by the Scientific Section, and Committees E and U of the society decided to cooperate in inspecting and supervising the tests, proper specifications to be drawn up by these committees. The members of these committees and the Scientific Section conducted laboratory tests that served as a check upon the previous investigations and gave information upon which to base the main field tests. The plates used for the tests were rolled from three kinds of metal—ordinary open-hearth structural steel, ordinary Bessemer low carbon steel, and pure ingot iron. In this way we will secure data relating to the resistance to corrosion of certain metals when tested out simultaneously with others. The steel plates were painted in two ways, part of them being scratch-brushed in the ordinary way before painting, thus following out the usual mode of painting structural steel, and part of the plates being pickled in sulphuric acid, in order to completely remove the scale, and the plates were subsequently washed with lime, so that all traces of the acid were neutralized.

The test was conducted in a thoroughly systematic and practical manner, following out the methods employed during the tests already made at Atlantic City and Pitts-

burg. The Master Painters' Association co-operated with us in the work and gave us the benefit of their practical experience in this line. Inspectors and painters, representing the committees and sections, were upon the ground throughout the work.

CHAPTER VI.

THE SWEAT-BOX OR ACCELERATED FIELD TEST FOR DETERMINING VALUE OF STEEL PAINTS.

Very few corporations, whether manufacturing paints or buying paints, and very few engineers or architects have the facilities or the time to make exhaustive laboratory research when choice is to be made of a protective coating for their use.

Accelerated Steel Rusting Field Test for Office

It is necessary to give the practical and busy man who needs some guidance on this question a simple and sure measure, even though the measure be only a fair approximation of the behavior of one paint as against another, and of any one material for a paint as against any other material, and all with reference to the results upon steel and iron. The method of testing by Harry Smith, in 1899, is not adapted for this purpose.

With this end in view, the following test is suggested:

The idea of this test is to duplicate as exactly as possible, on the most convenient and smallest practical scale, the conditions under which the steel has to perform actual service over a term of years, and to obtain, in a few hours, results on various materials, which results, by comparison amongst themselves, will give a fair indication of the results which will show on structural steel over a term of years when protected with these various materials.

This accelerated field test consists in subjecting strips of any particular kind of steel that may be chosen to an atmosphere of maximum humidity, the steel being in intimate contact with the materials concerning which results are desired.

What the practical man—either the paint manufacturer, the architect, or engineer—requires, is to have some practical result, easily obtainable, which will give him, in a

definite and visible manner, a criterion and measure of the value of the new discovery, and of the refined laboratory work.

The apparatus is extremely simple, and the test can be started at thirty minutes' notice by any manufacturer, architect or engineer, at his office desk, and can yield him visible results in two days thereafter. Before giving the detail of how to run this test, acknowledgments should be made to Dr. Cushman for outlining the manner in which the writer might work out this apparatus.

Dr. Cushman made the first practical accelerated field test, and his method is as follows: He took a polished sheet of steel and painted sections of it with the various materials ground in water, and then placed them under wet blotting paper for forty-eight hours, after which he washed the plate, and the steel then showed in the amount of rusting which had occurred the characteristic behavior of each one of the materials in regard to the rusting of steel.

The idea was original with Dr. Cushman, and it is to him we will owe whatever practical apparatus may be evolved along these lines.

Permission was requested from Dr. Cushman to work it up in some practical way for the manufacturers of the raw materials and of paints, and for the consumers who have the work of protecting structural steel.

The materials required are as follows:

An ordinary deep cigar box.

2 or 3 sheets druggists' thick filter paper.

1 dozen thumb tacks.

1 dozen safety razor blades (unless some special steel is to be tested).

$\frac{1}{2}$ dozen small butter dishes or saucers.

Each of the dry materials to be tested.

A clean pencil for stirring.

A pocket knife.

A glass of water

An old towel or rag for cleansing hands, pencil, etc.

A piece of emery cloth.

Origin of Test

Materials
Necessary for
Sweat Box

A tooth brush.

2 or 3 test tubes.

The chemist, engineer or architect who wishes to conduct this test on actual paint products instead of the materials used in the manufacture of paint products, may proceed as follows:

Recovery of
Pigments
from
Liquid Paints

In addition to the list of materials given, add a \$5.00 centrifuge apparatus made by Bausch & Lomb, in other words, a small laboratory centrifugal machine holding test tubes.

Number the test tubes for reference purposes and place in each test tube a small sample of the paint to be tested, together with a large quantity of benzine.

Actuate the apparatus and most of the vehicle will be thrown away from the pigment and the pigment will settle toward the bottom of the tube.

Decant or pour off the oil, add more benzine, thoroughly shake and pour off the liquid. Do this two or three times until the oil has entirely left the paint and nothing remains but the dry, clean pigments.

Then take the pigments and proceed with the whole test as described below for the testing of dry pigments.

Sweat Box
for Testing
Pigments
on Steel

Line all six interior surfaces of the cigar box with the filter paper, using the thumb tacks for the purpose. Thoroughly wet the lining of the cigar box with water and stand it on one edge so that when it is ready for use it will be free from drip.

Place upon a piece of filter paper, large enough to cover the hand, some of the material under examination, add a few drops of water and rub up with the finger into a rather soft paste, this being easily accomplished with nearly all pigments, and bringing into a paste many pigments which are otherwise extremely difficult to incorporate with water. Be particular to cut the surface of the razor blade to the raw steel with 00 emery paper, to insure the removal of any lacquer or surface treatment of the blade. It is necessary to handle the razor blades by the edges so as not to get any finger marks upon the surface. Now place a cleaned razor blade upon the plate,

fold over the filter paper on each side of the razor blade in such a manner as to completely cover it with paste-coated filter paper, and place blade, paste and paper upon a butter dish within the cigar box.

Dr. Cushman prefers to use ordinary kitchen knives which may be obtained at any hardware store at \$1.00 a dozen.

Treat each sample of material under test in the same manner.

In the case of materials soluble in linseed oil, such as resins and linoleates, these are to be dissolved to a heavy solution in benzol, and a coating poured upon the razor blade. The evaporation of the benzol leaves upon the surface of the blade a thin film of the material to be tested, and, because of the fluidity of the benzol and consequent thinness of the film, a second coating is advisable. The coated blade is then to be placed in a butter dish within the box along with the other materials with which it is to be compared. Care should be taken that the plate is completely coated as there is a tendency for the liquid to segregate on the steel.

A word of caution is necessary regarding the testing of the inhibitives such as the chrome soaps, that are soluble in linseed oil.

These are not pigments, but soluble in the oil and vehicle constituents and therefore must not be applied in a water paste, but in a film, through the agency of benzol as above described.

If a strip of steel in every case be treated with potassium bichromate in such a test, a convenient standard of minimum corrosion will be afforded, for purposes of comparison.

If so desired, in the foregoing test the operator may increase the quickness with which the test may be performed, by adding to a little bicarbonate of soda (baking soda) on a butter dish, a little sulphuric acid. An evolution of carbonic acid gas will ensue and as this gas rapidly stimulates corrosion, its presence will render the test still more positive.

Caution
Regarding
the Testing of
Vehicle
Soluble
Pigments

Standard
Test

Quantitative
Test
with
Sweat Box

A considerable degree of refinement and a fair index of result can be obtained from this apparatus if the strips are first carefully weighed in a laboratory balance, and then reweighed after the steel is scrubbed with a tooth or nail brush to remove any rust formed, in which case the loss in weight of the steel is the measure of the rust formed and the degree to which the pigment has stimulated rust.

It is evident to any man who will compare the conditions in this test with the field conditions, that practically all of the important factors which contribute to the corrosion of steel are present in this test in such a way that they will indicate in a short time the results which would be obtained from the steel painted with a paint coating produced from these materials and over a considerable length of time.

Inhibitive
Pigments
Necessary
in Paint Films

When we consider that the dried linseed oil or coating of linoxyn is permeable to water, and that, with successive changes in the weather, in an outside field test, we have produced conditions where the steel is exposed to air saturated with moisture (both of which have penetrated the linoxyn), and when we further consider that this moisture, which has penetrated the linoxyn, may carry to the surface of the steel the materials from the paint film, we thus see that in the open air field tests extending over a long period of time we have many different periods during which the steel is exposed to moisture carrying the materials of paint, either physically or in solution, and, therefore, in this accelerated field test apparatus the steel is throughout the test, from beginning to end, thus exposed to excessive humidity and in physical contact with the material concerning which we need information.

We have thus in the apparatus the material moistened with water in intimate contact with the surface of the steel, and the difference between this accelerated field test apparatus and an actual field test is the continued humidity and the immediate and positive treatment of the surface of the steel with the material in question.

In this apparatus it is planned to entirely dispense with the delicate manipulations of the chemist with his determination of the power of these various materials (when conveyed from the paint films to the surface of the steel) to act as electrolytes. We also leave to one side the aid of physical chemistry to determine the dissociation of these various materials in solution, which indicates to the chemist their power to retard, arrest, or stimulate corrosion, and we leave to one side the aid of the electrical laboratory to determine whether these materials are electro-positive or electro-negative to steel, and we avoid in this test the necessary skill of the chemist and the aid of the laboratory in making refined tests on the corrosion of steel in the presence of these materials in laboratory apparatus.

The Sweat Box
Test for Use of
Engineer and
Architect

SUMMARY OF DISCUSSION

In the course of the discussion which followed the reading of the paper several statements were made by Mr. H. A. Gardner, Assistant Director of the Scientific Section, in answer to questions brought forth by the reading of Mr. Perry's paper. A brief outline of these remarks is herewith given.

The inhibitive effect of certain pigments may be asserted in cases where these pigments are mixed with pigments having a stimulative rather than an inhibitive nature, if the net stimulative force is well-subordinated to the net inhibitive force: for instance, in the case of a pigment which strongly conducts electricity and therefore promotes galvanic action, an admixture with a thoroughly inhibitive pigment in sufficient quantity would render the mixture inhibitive. In a case of this sort, when inhibitive and stimulative pigments are mixed, two contending forces are at work, and there will be required a considerable amount of the inhibitive pigment to overcome the corrosive action of the stimulative pigment.

The high price of a thoroughly inhibitive pigment, such as zinc chromate, for instance, precludes its admixture in large percentage within such a compound unless the cost of the paint is no object to the consumer. The public, however, as a rule, demands a paint at a reasonable price, and it is, therefore, advisable for the manufacturer to design a paint with pigments all of which are either inhibitive or non-stimulative in nature. It is self-evident that where inert or non-stimulative pigments are used, only a small percentage of inhibitive pigment is necessary to render such a compound safe for use on steel and iron. Such a paint can be prepared and sold to the consumer at a reasonable price compared with the price of the old "rule of thumb" so-called, anti-rust paints that have heretofore been used.

It has been found that certain black pigments which were most

stimulative in their nature have given fair service in some cases, for a year or more, and this is explained by the fact that these pigments have been good water-shedders and would, in many cases, be called greasy by the painter, and they possess, moreover, excluding properties because of their physical nature. Thus they have given, when painted out, a film fairly impervious to moisture and gases. After a period, however, such a paint coat will fail, and then the water and moisture and gases of the atmosphere being admitted, most serious evil is started; galvanic action ensues and the steel shows immediate corrosion, which works well under the paint coat itself. Because of the hiding power of black paints, the result is hidden from the eye of the casual observer, and the corrosion is not very evident. It is necessary for the engineer to make more than a superficial examination in order to detect corrosion in such cases. The most serious and dangerous form of rusting often proceeds beneath these black coatings, and is unobserved until too late. The hiding effect of the black paint prevents the rust from being seen. For this reason, it is particularly necessary that the prime coat applied to steel be a rust inhibitive and a non-conductor of electricity. The succeeding coats, however, need not be, in every case, of the same high character as to inhibitive qualities, and, for this reason, those blacks which are such good excluders, but very active stimulators, may perhaps, in some cases, be used as top coats when thus insulated from the steel by the inhibitive prime coats, if inhibitive paints for the top coats of equal excluding qualities are not available. It is, of course, safer to use inhibitive coats throughout.

A variety of red leads are found on the market and, although each shows somewhat different values as rust inhibitives, as a rule they all belong to the inhibitive family; but this group is not near as inhibitive as the group included under the zinc chromate list. This same law applies to the zinc chromate pigments, as there is a marked

difference in the varieties which may be prepared. Zinc chromates head the list of inhibitive pigments in solid form.

The present science of rust inhibitors has given us information to show that a safe mixture to use on steel and iron may be prepared by the use of a neutral oxide of iron, free from sulphuric acid and sulphate of lime, and mixed with a small percentage of zinc chromate in the pigment part. The vehicle for such a paint is benefited by a percentage of treated oil to help render the film a better excluder. The maximum inhibition of corrosion may be obtained by rendering the vehicle for such a paint also thoroughly inhibitive. This may be accomplished by the use of about 5 per cent. chromium resinate, a chromium compound soluble in linseed oil. Such a paint would be entirely safe to use on tin plate for roofing and other purposes, and it has been pointed out that the cause of failure of so many paints used on tin roofs has been due to the stimulative character of the pigments contained in their composition.

The action of the National Association of Master Sheet Metal Workers, in condemning certain black paints, has been cited, and this action was brought forth by the practical experience and observation of the tinsmiths and manufacturers of tin plate, and confirms the statements herewith made, regarding such pigments.

That a very few black pigments are safe to use has been shown by laboratory tests, but the average producer of paints is not familiar enough with the science of rust inhibition to be able to choose such material, unless he awakens to the importance of the tests now being conducted and follows out a similar line of investigations. Tin plate always contains points of untinned surface, which allow corrosion of the under surface to go on underneath the tin coating, and these points of attack are very visible when a layer of slightly acid ferroxyl indicator (5 per cent. solution of gelatine containing a trace of potassium ferro-cyanide) is poured over a tin plate. Beautiful blue spots form very soon after the test is started, wherever a pin hole is present.

To Dr. William H. Walker belongs the discovery and credit of these tests, and he has developed it so that it may be used in the tin plate factory, where a quick test is demanded.

Mr. W. O. Quest, Master Painter for the Pittsburg & Lake Erie Railway, stated: "The tests he made with chromic acid three years ago conclusively show that this compound has exceptional qualities, and is a retarder of corrosion."

Tests started later by Mr. Quest at the suggestion of the Scientific Section are also offering remarkable illustrations of the value of this compound when properly combined in a paint designed to be used on steel surfaces of various kinds.

Chromium resinate or chromium linoleate are among the best inhibitives that we have today, as the result of the latest work in rust inhibition, and it may be well to state that these are compounds of chromic acid combined in an organic form with the acid radical of oils. The use of about 5 per cent. of this material in the vehicle of a paint renders the paint absolutely inhibitive in the vehicle portion. This peculiar action is due to several reasons: In the first place, because of the low value of dissociation possessed by the acid radical contained in its make-up; second, because of the ability it possesses of rendering steel passive, possibly polarizing the surface thereof; and, third, because it probably has the ability of ennobling the iron or steel upon which it is applied, raising the metal to the tri-valent form which is unattacked by corrosive agencies. Being thus provided with a compound that prevents electrical excitation and consequent rusting of the metal it is in contact with, we are able to use this material as an integral part of a paint to be used for the protection of steel and iron.

It is of extreme importance to secure a coating which will protect under the most severe conditions which obtain, such, for instance, as on steel cars, these cars being hauled through various parts of the

country, constantly subjected to changes in temperature in the various climates through which they pass and to the abrasive action of wind and sand and roadbed dust, all being factors which quickly destroy the film and accelerate early decay of the metal underneath.

These cars may be subjected to the saline drip of the tunnel and the sulphurous gases from the engines constantly condensing on the surface of the cars, and it is extremely important that the highest grade paint coating be used for such work.

In designing a paint to properly serve under such conditions, it is necessary that a proper selection of the pigments from the inhibitive list be made, and at the same time the paint designer should be very careful to obtain strength of coat and again he should obtain impene- trability of the paint coat by observance of the law of the use of three or more particles of different determinate sizes, as applied to paint.

The inhibitive value should also be considered in the vehicle, as well as in the pigment, and the maximum exclusion should be secured by the proper selection of the oils and gums for the vehicle.

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Bulletin
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Preliminary Booklet—Addresses on Paint, Delivered Before the Michigan Chapter, American Institute of Architects, 1907.

1—Tables of White Pigments and Vehicle—Standard Nomenclature.

2—Standard Can Sizes Recommended to Paint Manufacturers.

3—First Report on the Test Fences Erected by the Scientific Section.

4—Methods for the Analysis of the Vehicle Constituents of Paint.

5—Tests Upon the Corrosion of Iron to be Conducted by the Scientific Section.

6—First Annual Report of the Scientific Section.

7—Preliminary Report on Steel Test Fences

8—Report of Committee "E" on Preservative Coatings for Iron and Steel.

9—Recent Technical Developments in Paint Manufacture.

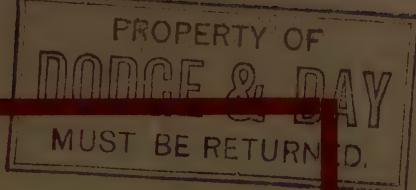
10—Protective Coatings for Conservation of Structural Material.

11—The Corrosion of Iron and Steel. *By Alfred Sang.*

12—The Function of Oxygen in the Corrosion of Metals. *By William H. Walker.*

13—Protective Coatings for Steel and Iron. *By Robert S. Perry.*

14—Coatings for the Conservation of Structural Material. (In press.)



**Coatings for the
Conservation of
Structural
Materials**

By R. S. PERRY

**Scientific Section
Paint Manufacturers' Association
2200 GRAYS FERRY ROAD
PHILADELPHIA, PA.**

Delivered at
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Coatings for the Conservation of Structural Materials

By R. S. PERRY



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PREFACE

This paper was presented before seven hundred students at Lehigh University, on February 26, 1909.

As is well known, Lehigh University graduates every year a very large number of technical men: electrical and mechanical engineers, architects, chemists, and metallurgists, all of whom seek employment in the great industrial institutions of our nation. These men carry with them the new thought and light which scientific investigations have brought forth, and institute these ideas into commercial practice, developing them finally into exact science.

It is evidently important that these men should receive a better knowledge of the important subject of protective coatings than is usually acquired by students, and the purpose of this paper is to present to them the latest work on this subject.

While there has been previous publication of some of the work contained herein, it is believed that the data is of such import to the young technical man, that it is advisable to bring it to his attention by incorporating in this paper.

Our hope for recognition of improvements in our industry lies with the type of men to whom this paper was addressed, and by their recognition of the scientific truths brought forth herein, and with a prompt application of these truths in commercial practice.

R. S. PERRY,
Director Scientific Section.

COATINGS FOR THE CONSERVATION OF STRUCTURAL MATERIALS

By R. S. PERRY.

This subject deals with all forms of American property that are artificially created, from natural resources such as iron and lumber and which are erected into reasonably stable form, such as pipe lines, stand pipes, bridges and buildings, and also with another wide range of property of stable form, but purposely movable, as for instance, the woven wire fencing of the western farmer, most forms of machinery and practically all railroad and marine equipment.

Its conservation covers human effort and human means to prolong its life, and to lessen its rate of waste, decay or depreciation.

Efforts to preserve structural property have in the past taken two forms, namely, the improvement of the structural material itself so that it may better resist agencies of decay and destruction and again the improvement of coverings or coatings, to exclude the agencies of decay.

A new method of prolonging the life of such property is now just about to be developed, in the productions of coatings which will not only exclude the agencies of decay, so far as possible, but which will contain within the coating itself materials which may be said to be antiseptic or counteracting to the agencies of corrosion of iron and steel.

In this discussion we will not deal with the less perishable materials, such as bricks, cements, and stone, we will only touch upon the protection of lumber and will study more particularly the preservation of structural iron and steel, where these materials are exposed to out-of-door conditions. In other words, we will consider the preservation of our most important and perishable materials, iron and steel—where they are most exposed—out of doors—to agencies of decay.

The subject may seem, on first thought, to be entirely a matter of technical detail, and also one of expediency, to be a matter which can only be of interest to the engineer or corporation officers concerned in the up-keep of property, and to be a matter in which the engineer may be allowed to balance the cost of protection and prolonged life for the structure against the money which it would cost to replace the same.

A study of the comparative costs of coatings versus the cheapest structural iron and steel even for the crudest and cheapest purposes where exposed, will show that the cost of the most expensive coating is negligible compared with the value of the iron and steel, and that one extra year of life will compensate for the most expensive coating.

The reasonable preservation of American property in the shape of structural material passes beyond the question of business expediency, and, upon reflection, is found to be a moral and civic duty.

It can be shown that all reasonable effort to perpetuate the value of structural material means the conservation of a vast portion of the wealth of our nation.

The American people have bestirred themselves and are now awake to the necessity of conserving that portion of our wealth as yet undeveloped, which we term our natural resources, and American civilization is rapidly adapting itself industrially, economically and politically to this, but the public conscience and the public thought are not yet quickened to the conservation of those natural resources which have been already converted into American property or, in other words, to the conservation of the *converted* resources of this country, largely existing as structural material.

Questions of present expediency have, in a broad way, governed up to the present time.

The American attitude on this subject is largely that of the contracting carpenter who enforces a regulation that his carpenter's time in driving nails is more valuable than the nails which he drops, and that he must not stop to pick them up.

Again, our corporations, in their desire to produce results for the

stockholders, and in the stress of competition, when investing their moneys in plant, whether industrial, factory or railroad, have been prone to economize at the point where extra investment would mean maximum or ultimate life for the physical property, thus curtailing the amount of money tied up in plant account, and thus increasing the percentage of capital in quick or fluid form to handle a large output and thus again increasing the return possible on given investment, but at the expense of the stability of the investment.

This means that in the desire to show quick returns, plant account is apt to be curtailed at the point where a small increase in the same would mean a large increase in permanence or life of the physical property, but the manager responsible to the stockholding owners can show larger dividends or returns for the total amount of money entrusted to him in the given enterprise, and can leave to the next generation or to the vicissitudes of business the two problems of, first, heavy depreciation and, second, rebuilding.

If we turn from investment to maintenance, and if from the question of the investment in new property we turn to the policy governing maintenance of plant and equipment, we find the same tendency toward present expediency at the expense of permanence.

Many a purchasing agent is more concerned with the showing he can make in his annual budget under the heading of the purchasing of supplies for maintenance, and is more interested in making a record which will show favorably for the conduct of his office over a short term of years or against his predecessor or even against the previous year of his administration than in the eventual and total term of life of the property for which maintenance and repair supplies are purchased.

In the case of rolling stock, bridges, structural building material and kindred investments, the purchasing agent of a large corporation can hardly be blamed for looking most carefully to present cost of maintenance rather than to the ultimate life of the property, because, as a people, the American business man has not yet properly appreciated that the steady rise in the cost of all our structural materials means an excess on

a replacement bill over the original cost of the material destroyed by age, more than equal to the total cost of the most efficient and scientific maintenance.

Sixty years ago our country was a vast store-house of natural resources and natural wealth which stood unimpaired.

The Civil War marked the beginning of a half-century, during which we have converted these undeveloped resources into physical property on a scale which has been unprecedented and has made us a rich, populous and well-equipped nation of the first class.

The American pioneer, with courage and self-denial wrested from a virgin continent control and possession of vast natural resources.

The pioneer's son, during the last half of the nineteenth century, converted this natural wealth into possessions and the equipment of civilization to an astonishing degree. The civilization of the pioneer was scantily equipped and left the natural resources of our country practically untouched and unimpaired. With the beginning of the twentieth century, we hear the note of alarm, sounded by far-sighted and patriotic men, and they tell us that we have been converting our resources wastefully and at too rapid a rate, and that we must conserve each possible ton of iron ore than can go to the furnace, where it is possible to concentrate it from the waste gangue of the mine and to save it from the dump heap—that we must so administer our coal mines that the practice may be stopped, of taking the accessible portion of a vein and leaving those portions which, at a somewhat greater expense, could be won in spite of slate partings and weak roofs; that we must cut our lumber with such discrimination that nature can reproduce the forest and that timber below a reasonable diameter should be left behind; that our water-sheds should be protected, in order that our water powers and the navigation of our rivers can be developed to a high efficiency; that the farmer should cultivate his land with rotation of crops, that he need not be forced, as in the past, to abandon worn-out fields and seek virgin soils.

American common sense has been quick to respond to these notes of warning, and our nation is adapting itself to the conditions which can

alone give our descendants a heritage commensurate with the possessions which we have enjoyed, and of which we are now able to avail ourselves.

It is readily seen that the natural resources of America, when converted, present themselves in two great items: arable land and structural material.

With arable land, our discussion does not concern itself, but the products of our forests and of our mines, such as coal and iron, are largely converted into structural material, whether the same exists in buildings or in property, such as railroad plant and equipment.

It is equally true of a nation as of a man, that if through fortunate circumstances and by energy and ability, productiveness may exceed expense and waste, with the resulting accumulation of property or wealth, yet in the end the net value of either man or nation, in a material sense, must be measured by the efficiency with which man or nation conserves and properly administers expenditure, so that expenditure shall be wisely subordinated and moderately proportioned to income or wealth.

It is true of man, family and nation, that those only retain wealth and property where the property is carefully conserved and waste is sufficiently eliminated.

If it is necessary that our natural resources shall be more carefully conserved, and that we shall draw upon them in greater moderation and, if it is true that we must get the last ounce of value from the ores coming from our mines and the timber from our forests, then it is conversely true and equally important that we must conserve and give a maximum life to the vast wealth already invested in American property in the shape of structural material.

When we approach the question of conserving and prolonging the life of our structural materials, we find that mankind uses protective coatings as the one broad means for this purpose.

For the purpose of this discussion, we will confine ourselves to the use of paints for protecting those iron or steel surfaces exposed to out-of-door conditions, which conditions are, of course, the most extreme and most apt to shorten the life of the steel or iron.

THE PROTECTIVE COATINGS OF ANIMATE NATURE.

Investigation of Nature's Protective Coatings

Let us now turn to animate nature and study the protective coatings she has created.

It can be noted that nature has provided, through no uncertain law, the best possible coating for each of these forms of organic life, and for the most highly developed, the most perfect coating.

In vegetable life, nature furnishes a coating for the season only, or, in other cases, new coatings perennially; the normal coat needs and has neither great strength nor impenetrability, but develops cellular structure rapidly to approximate the cellular fibre of the plant.

Coatings for Vegetation

In vegetable life, a wound is healed by a flow of sap to form a relatively thin coating, which, by oxidation, hardens into a viscous, semi-solid mass with characteristic power of internal elasticity and adjustment to strain, but rather soft, as its service is but temporary.

Coatings for Invertebrates

In the case of invertebrate life, where the safety from attack, accident or wear depends entirely upon the coating, the coating is formed from liquids, but changed to a solid, containing a high percentage of mineral constituent to impart strength and hardness.

Coatings for Vertebrates

Vertebrate life shows us a triumph of nature in protective coatings, the animal and human skin in its various forms.

This covering is produced, like the others, from the circulating liquids of the living structure, which gradually oxidize to a semi-solid mass, as nature may require.

Nature here declares in positive terms that where a hard surface is needed it shall be provided; and, accordingly, produces claws, nails, etc., of more solid structure and with a higher percentage of hard mineral matter. Again, nature declares that this most perfect protection she provides, the human skin, shall have three layers, or skin coats, if we include the glassy coating, all infinitely close in their interrelation, but giving wonderful adjustment to accommodate the expansion and contraction of the substructure to any sudden or slow change of form.

To summarize these observations: nature tells us that her best protective coats have been formed of a viscous organic fluid that can readily adapt itself, and which, by progressive oxidation, forms an elastic skin, capable of great internal adjustment to strain; that this skin should be three-fold, or three-ply, and that where wear is needed this coating should be hardened by mineral components.

THE LAW OF MINIMUM VOIDS WITH THE USE OF PIGMENTS CONTAINING PARTICLES OF PARTICULAR OR DETERMINATE SIZES.

A careful consideration of the combination of solid material with a semi-fluid vehicle, shows that in many respects the problems are identical with the problems involved in the preparation of concrete.

The Analogy
of Coatings
to Concrete

Just as with concrete, the problem is to produce strength with the minimum of voids by using a mixture of particles of three or more determinate or characteristic sizes, just so, in the coating of paint, a minimum of voids and a maximum of imperviousness can be obtained by a wise selection of three proper materials which supply these three different determinate or characteristic sizes of particles.

The Law of
"Minimum
Voids"

In addresses before the American Institute of Architects, at Detroit, and before the American Society for Testing Materials, both in 1905, the writer, by scientific deduction, suggested as a scientific law, that pigment particles of two or more determinate or characteristic sizes must be used to give a paint proper density and durability, that the particles of pigment must be of several sizes to fill the voids properly.

Relation of
Pigments to
Density and
Durability of
Paint

To-day it is possible to prove and confirm this law by a simple yet striking experiment.

We can first demonstrate that a film of dried vegetable sap or oil, such as linseed oil, which the chemist calls linoxyn, is filled with what the cement expert calls "voids" and is porous, and the following table will show the rapidity with which carbonic acid gas actually passes



Bell Jar Apparatus for Testing Permeability of Paint Films

through such films of linoxyn with various pigments incorporated or ground into the oil. Taking the porosity of a film of oil and asbestine as 100 per cent., on two hours' treatment we find as follows:

Porosity of Asbestine film	100.00%
Porosity of Corroded white lead film	89.10%
Porosity of a high grade Composite base paint film containing white lead, asbestine and zinc oxide	71.00%

Again taking the porosity of Zinc Oxide at 100%, we find as follows:

Porosity of film of Zinc Oxide.....	100.00%
Porosity of film of Zinc Oxide and a small quantity of Barytes.....	58.00%
Porosity of film of Zinc Oxide and small quantities of Barytes and Blanc Fixé,	54.00%

**Experiment to
Prove a Paint
Film of
Composite
Pigments is Less
Porous than a
Single Pigment**



Bottles Showing Relative Permeability of Films by Amount of Whiting Formed Within

Now, let a number of films of linoxyn be prepared, the first containing, say, one pigment, such as barytes, another containing two pigments, such as barytes and blanc fixe, and a third film, carrying three pigments of

different sized particles, for instance, barytes, blanc fixe and zinc oxide; let these films be used as covers or seals for as many glass receptacles.

It will be noted that the barytes has the coarse particle characteristic of a natural mineral, and that the precipitated blanc fixe has a smaller but characteristic size of particle, resulting from its precipitation from solution, while the zinc oxide has an infinitely fine size of particle, due to its formation from a fume, a particle size so fine that while passing over as a fume from the furnace to the solid form, it shows characteristics of gas tension.

Let us place in these glass receptacles, previous to sealing, a reagent or chemical which will absorb carbonic acid gas and fix it chemically in such a way that we can measure or weigh it. Ordinary lime water, which can be purchased in any drug store, will do this, and will form, with the carbonic acid gas, calcium carbonate, or common whiting.

Porosity of
Films Relative
to Size of
Voids

If these receptacles be now placed in a tight room or container filled with carbonic acid gas at somewhat above atmospheric pressure and so that the gas is pressing equally on each skin, it is evident that we can measure the relative porosity or sponginess of each film by the amount of gas which it allows to pass through from the outside into the container which it seals. Thus we obtain a comparative measure of the effectiveness of any pigment or group of pigments taken to close the pores or voids which have been mentioned as existing naturally in the linoxyn itself. The average results obtained from a number of such experiments show that beyond all question pure linoxyn without pigments is extremely porous. It is also shown that a paint must have pigments in it; that one pigment does part of the work of filling the voids; that two do more of the work; but that, if three or more pigments of different sized particles are used to make the paint, we get much better excluding values and go a great step forward in making the paint skin sufficiently impervious to gas. Similar experiments yield the same result with regard to moisture.

In the pigments chosen, the size of particles varied greatly. Barytes particles are naturally large, while blanc fixe is of medium fineness and zinc oxide about the finest pigment we know of. It is of interest to note that white lead by itself, because of the great variation of its particles, comes more nearly to filling the necessities of the paint coating than any one other pigment alone, but white lead alone does not fill the pores or voids sufficiently.

This work thus proves that exactly the same law obtains in making a paint coating which is a sufficient water-proof or excluder of agencies of decay, that exists in making a good concrete. No one would attempt today to make a good concrete out of one material, such as the sand alone or the broken rock alone, with the liquid vehicle of water and cement.

It has thus been shown that it is necessary to use a fluid or vehicle for producing the coating and one which will give accommodating elasticity.

It has been further shown that it is necessary to use pigments to render the paint coating more impenetrable to gases, moisture and other agencies of decay, by the use of pigments or particles of three or more characteristic or different determinate sizes.

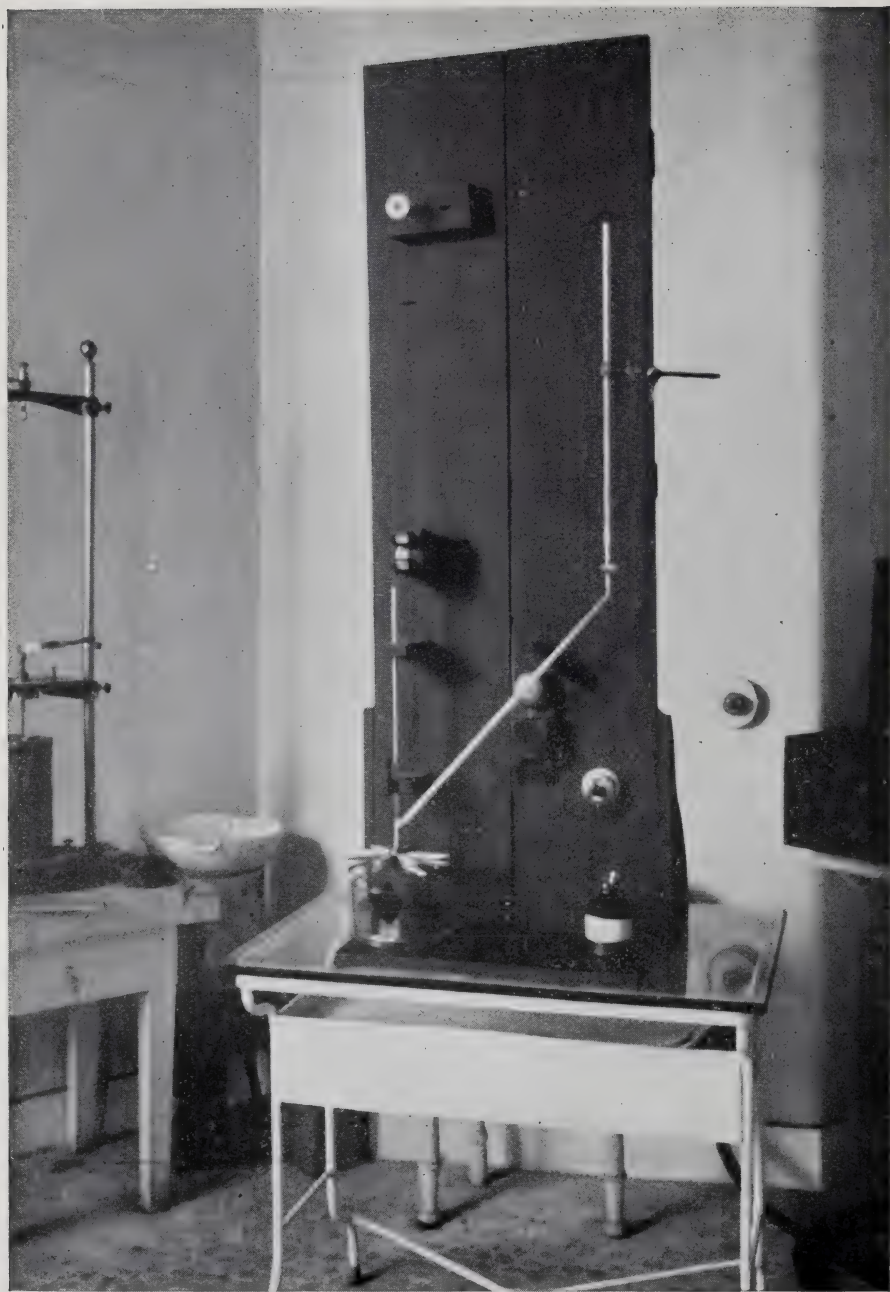
If we take paint films composed of various pigments and test them with the Perry Film Testing Apparatus, which gives an approximate measurement of the elastic limit, or limit at which a paint skin, composed of linoxyn and the pigment, will break, we get data which show that certain pigments should be largely used to preserve or, rather, to avoid depletion of the elasticity of the linoxyn; the experiment also shows that other material with extremely fine particles should be used in fairly liberal proportion to fill the pores, but that excessive use of a pigment of this kind will destroy the proper elasticity of the film and produce cracking and peeling.

We also find that asbestine, or similar materials with needle-like structure, used in moderate proportion, add wonderfully to the strength of the paint coating. Thus the

Laws on
Concrete Apply
in Making
Paints

Elasticity from
the Linoxyn

Strength and
Elasticity of
Paint Coatings



Film Testing Machine

result of human experience in compounding high grade paints is confirmed by the apparatus which measures the porosity of the paint, and again by the apparatus which measures the elasticity and strength of the film.

THE INHIBITION OF THE CORROSION OF STEEL AND IRON AS STRUCTURAL MATERIALS.

The direct relation of the materials used in paint, to the corrosion of steel and iron, and the extent to which they might stimulate decay, seems never to have been investigated. Also, the possibility that ingredients might be used which would act as antiseptics or inhibit the corrosion of iron and steel, seems to have occurred neither to the manufacturer nor to the public. The researches of Dr. Allerton S. Cushman, of Dr. William H. Walker, and of other scientists, equally well known, have during the past two years awakened both the manufacturer and the public to this problem, and it has been clearly demonstrated that there is an important and measurable difference between the behavior of various materials used in the paint business, and that some of them conserve while others tend to destroy the underlying structure.

Turning, therefore, to the conservation of structural iron and steel, and to its rust inhibition through particular coatings, we have the problem of choosing the proper materials for manufacturing a paint which will both exclude the agencies of rusting, and which, when moisture and gases do penetrate the coating, will inhibit the iron from rusting; and we also have the problem of giving to the chemist, engineer and architect some simple method of determining whether any given paint is, in at least rough measure, harmful, safe or beneficial.

It has been absolutely demonstrated, and all technical men acquainted with the subject are agreed, that linseed oil, when dried to a coat of linoxyn, has voids or pores in it.

The paint manufacturer uses a combination of pigments which largely fill these voids, but the most care-

Preservation of
Steel and
Iron

Permeable
Nature of
Oil Film

fully prepared coat of paint for lumber, when the vehicle is linseed oil, without the addition of varnish, is always somewhat porous, and the moisture has some opportunity to pass out without blistering, etc.

Structural Steel
Requires a
Non-Porous
Film

In the case of structural steel we have no moisture in the structural material to contend with, as we have with lumber, and, therefore, we can safely add varnish gums in solution to the linseed oil, thus producing a more nearly water-proof coat to the agencies of decay.

Varnish Gums,
in Oil,
Reduce
Porosity

The action of the gum, diffused throughout the linseed oil by solution, is to help to fill up or fuse together the pores or voids, or, in other words, to render the lin-oxy film more resistant to the entrance of moisture and prevent the passage of moisture through the paint coating to the structural material.

Anti-Rust
Paints
Improved by
Gums in
in Vehicle

This is the conclusion reached from the standpoint of technical research, and practical experience has also demonstrated that those coatings which have been proved the best protection for steel, have invariably contained a vehicle in which some gum or varnish material has been present.

It is a fairly safe generalization that the vehicle should thus be so modified as to produce a more fluid and less porous coating for structural steel and iron, while at the same time the paint must be most carefully compounded, so far as the solid pigments are concerned, to give a minimum of voids and a maximum of strength and of durability.

Necessity for a
Blend of
Pigments to
Fill Voids

If the conditions which give impenetrability, physical strength and durability have been observed, the one other precaution which is necessary is to avoid the use of any pigment which would be chemically active, either with regard to the vehicle or with regard to the structural steel and iron.

The choice and criticism of a paint formula for iron and steel should proceed along the following lines and by a process of elimination:

All the pigments available, for use as the chief or preponderating base or percentage for such a paint may be

divided into pigments which are poor excluders of agencies of decay, or which, in other words, yield porous films and pigments and those pigments which yield impenetrable or water-shedding paint-coatings, or which a painter would be apt to designate as greasy in their nature.

Preference should be given to the latter group, and again, in this group of excluders, those pigments should be rejected which are rust-stimulative and preference given to the resulting and remaining small group of rust-inhibitors and inerts.

Recent investigations into the nature of pigments have revealed the fact that they may be divided into three groups and termed Rust-Inhibitives, Inerts or Rust-Stimulators. The nature of the pigment itself, or the nature of the impurities contained within the pigment, are factors deciding the position of the pigment in one of the three groups or types above mentioned. It may be expected that the use of rust-inhibitive pigments in paints designed for the protection of steel surfaces will give to such a paint very valuable properties. Further consideration of the subject will aid us in selecting the proper pigments for such a purpose, certain compounds are of such a nature as to excite electrical action, and, consequently, stimulate corrosion, while still other compounds are of such a nature as to inhibit or prevent corrosion.

To the class of compounds that inhibit corrosion belong chromates. Aside from those chromates which prevent corrosion, we have those which act in an inert manner, also those in which any inhibitive value is overbalanced by the effect of impurities, showing a strong stimulating action in the rusting of metal. But a simple test will show in which class the chromates come.

Grouping of
Pigments into
Inhibitors
Inerts
Stimulators

Value of
Chromate
Pigments
as Rust
Inhibitors

THE SWEAT-BOX OR ACCELERATED FIELD TEST FOR DETERMINING VALUE OF STEEL PAINTS.

Very few corporations, whether manufacturing paints or buying paints, and very few engineers or architects

have the facilities or the time to make exhaustive laboratory research when choice is to be made of a protective coating for their use.

With this in view, the following test is suggested:

The idea of this test is to duplicate as exactly as possible, on the most convenient and smallest practical scale, the conditions under which the steel has to perform actual service over a term of years, and to obtain, in a few hours, results on various materials, which results, by comparison amongst themselves, will give a fair indication of the results which will show on structural steel over a term of years when protected with these various materials.

Accelerated
Steel Rusting
Field Test
for Office

This accelerated field test consists in subjecting strips of any particular kind of steel that may be chosen to an atmosphere of maximum humidity, the steel being in intimate contact with the materials concerning which results are desired.

What the practical man—either the paint manufacturer, the architect, or engineer—requires, is to have some practical result, easily obtainable, which will give him, in a definite and visible manner, a criterion and measure of the value of the new discovery, and of the refined laboratory work.

The apparatus is extremely simple, and the test can be started at thirty minutes' notice by any manufacturer, architect or engineer, at his office desk, and can yield him visible results in two days thereafter.

Origin of Test

Dr. Cushman made the first practical accelerated field test, and his method is as follows: He took a polished sheet of steel and painted sections of it with the various materials ground in water, and then placed them under wet blotting paper for forty-eight hours, after which he washed the plate, and the steel then showed in the amount of rusting which had occurred the characteristic behavior of each one of the materials in regard to the rusting of steel.

The idea was original with Dr. Cushman, and it is to

him we will owe whatever practical apparatus may be evolved along these lines.

Permission was requested from Dr. Cushman to work it up in some practical way for the manufacturers of the raw materials and of paints, and for the consumers who have the work of protecting structural steel.

The materials required are as follows:

An ordinary deep cigar box.

2 or 3 sheets druggists' thick filter paper.

1 dozen thumb tacks.

1 dozen safety razor blades (unless some special steel is to be tested).

½ dozen small butter dishes or saucers.

Each of the dry materials to be tested.

A clean pencil for stirring.

A pocket knife.

A glass of water

An old towel or rag for cleansing hands, pencil, etc.

A piece of emery cloth.

A tooth brush.

2 or 3 test tubes.

The chemist, engineer or architect who wishes to conduct this test on actual paint products instead of the materials used in the manufacture of paint products, may proceed as follows:

In addition to the list of materials given, add a \$5.00 centrifuge apparatus made by Bausch & Lomb, in other words, a small laboratory centrifugal machine holding test tubes.

Number the test tubes for reference purposes and place in each test tube a small sample of the paint to be tested, together with a large quantity of benzine.

Actuate the apparatus and most of the vehicle will be thrown away from the pigment and the pigment will settle toward the bottom of the tube.

Decant or pour off the oil, add more benzine, thoroughly shake and pour off the liquid. Do this two or three times until the oil has entirely left the paint and nothing remains but the dry, clean pigments.

Materials
Necessary for
Sweat Box

Recovery of
Pigments
from
Liquid Paints

Sweat Box
for Testing
Pigments
on Steel

Then take the pigments and proceed with the whole test as described below for the testing of dry pigments.

Line all six interior surfaces of the cigar box with the filter paper, using the thumb tacks for the purpose. Thoroughly wet the lining of the cigar box with water and stand it on one edge so that when it is ready for use it will be free from drip.

Place upon a piece of filter paper, large enough to cover the hand, some of the material under examination, add a few drops of water and rub up with the finger into a rather soft paste, this being easily accomplished with nearly all pigments, and bringing into a paste many pigments which are otherwise extremely difficult to incorporate with water. Be particular to cut the surface of the razor blade to the raw steel with 00 emery paper, to insure the removal of any lacquer or surface treatment of the blade. It is necessary to handle the razor blades by the edges so as not to get any finger marks upon the surface. Now place a cleaned razor blade upon the plate, fold over the filter paper on each side of the razor blade in such a manner as to completely cover it with paste-coated filter paper, and place blade, paste and paper upon a butter dish within the cigar box.

Dr. Cushman prefers to use ordinary kitchen knives which may be obtained at any hardware store at \$1.00 a dozen.

Treat each sample of material under test in the same manner.

Caution
Regarding
the Testing of
Vehicle
Soluble
Pigments

In the case of materials soluble in linseed oil, such as resins and linoleates, these are to be dissolved to a heavy solution in benzol, and a coating poured upon the razor blade. The evaporation of the benzol leaves upon the surface of the blade a thin film of the material to be tested, and, because of the fluidity of the benzol and consequent thinness of the film, a second coating is advisable. The coated blade is then to be placed in a butter dish within the box along with the other materials with which it is to be compared. Care should be taken

that the blade is completely coated as there is a tendency for the liquid to segregate on the steel.

A word of caution is necessary regarding the testing of the inhibitives such as the chrome soaps, that are soluble in linseed oil.

These are not pigments, but soluble in the oil and vehicle constituents and therefore must not be applied in a water paste, but in a film, through the agency of benzol as above described.

If a strip of steel in every case be treated with potassium bichromate in such a test, a convenient standard of minimum corrosion will be afforded, for purposes of comparison.

If so desired, in the foregoing test the operator may increase the quickness with which the test may be performed, by adding to a little bicarbonate of soda (baking soda) on a butter dish, a little sulphuric acid. An evolution of carbonic acid gas will ensue and as this gas rapidly stimulates corrosion, its presence will render the test still more positive.

A considerable degree of refinement and a fair index of result can be obtained from this apparatus if the strips are first carefully weighed in a laboratory balance, and then reweighed after the steel is scrubbed with a tooth or nail brush to remove any rust formed, in which case the loss in weight of the steel is the measure of the rust formed and the degree to which the pigment has stimulated rust.

It is evident to any man who will compare the conditions in this test with the field conditions, that practically all of the important factors which contribute to the corrosion of steel are present in this test in such a way that they will indicate in a short time the results which would be obtained from the steel painted with a paint coating produced from these materials and over a considerable length of time.

When we consider that the dried linseed oil or coating of linnoxyn is permeable to water, and that, with successive changes in the weather, in an outside field test, we

Standard
Test

Quantitative
Test
with
Sweat Box

have produced conditions where the steel is exposed to air saturated with moisture.

The rust inhibition of steel and iron is necessary; and in closing I will ask you gentlemen to turn these matters over in your minds, and render all possible aid to the solution of these problems.

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PUBLICATIONS OF THE SCIENTIFIC SECTION

BUREAU OF PROMOTION AND DEVELOPMENT PAINT MANUFACTURERS' ASSOCIATION OF THE UNITED STATES

Bulletin
Number

Preliminary Booklet—Addresses on Paint, Delivered Before the Michigan Chapter, American Institute of Architects, 1907.

- 1—Tables of White Pigments and Vehicle—Standard Nomenclature.
- 2—Standard Can Sizes Recommended to Paint Manufacturers.
- 3—First Report on the Test Fences Erected by the Scientific Section.
- 4—Methods for the Analysis of the Vehicle Constituents of Paint.
- 5—Tests Upon the Corrosion of Iron to be Conducted by the Scientific Section.
- 6—First Annual Report of the Scientific Section.
- 7—Preliminary Report on Steel Test Fences
- 8—Report of Committee "E" on Preservative Coatings for Iron and Steel.
- 9—Recent Technical Developments in Paint Manufacture.
- 10—Protective Coatings for Conservation of Structural Material.
- 11—The Corrosion of Iron and Steel. *By Alfred Sang.*
- 12—The Function of Oxygen in the Corrosion of Metals. *By William H. Walker.*
- 13—Protective Coatings for Steel and Iron. *By Robert S. Perry.*
- 14—Coatings for the Conservation of Structural Material.

PROPERTY OF
DODGE & DAY
MUST BE RETURNED

**PROTECTIVE
COATINGS
FOR
STRUCTURAL
MATERIAL**

By ROBERT S. PERRY



**BUREAU OF
PROMOTION AND DEVELOPMENT
SCIENTIFIC SECTION
PAINT MANUFACTURERS' ASSOCIATION
3500 GRAY'S FERRY ROAD
PHILADELPHIA, PA.**

PROTECTIVE COATINGS

FOR

STRUCTURAL MATERIAL

AND

DISCUSSION

AS PRESENTED AT A MEETING OF THE

WESTERN SOCIETY OF ENGINEERS

APRIL 21, 1909

BUREAU OF
PROMOTION AND DEVELOPMENT

SCIENTIFIC SECTION
PAINT MANUFACTURERS' ASSOCIATION
3500 GRAY'S FERRY ROAD
PHILADELPHIA, PA.

Protective Coatings for Structural Material

R. S. PERRY, PHILADELPHIA.

Presented April 21, 1909

Although it is the intention in this address to deal especially with the subject of protecting paints, and to adhere to this subject as closely as possible, it will be necessary to outline to you in a brief way some of the scientific investigations that have led up to the subject of rust inhibition, or the prevention of corrosion.

The United States government, two years ago, through the Department of Agriculture, started a series of tests to determine the causes of the rapid corrosion of the steel wire fences used by the farmers of the West to enclose the vast acreage of pastures and tillable lands. The complaints that the wire fences of today are found to corrode in less than one-fourth the time of the fences of twenty years ago have been found in many cases to be true, and the farmers and ranchers are justified in their demand for greater longevity for wire fencing.

Wovenfence
Failures
Start
Government
Investigations

Dr. Allerton S. Cushman who conducted the investigations found that the absence of certain impurities in the old time Swedish charcoal iron, the material largely used for wire fencing twenty years ago, was responsible for the rust resistance of this metal, whereas the steel of modern times contains impurities that cause its rapid disintegration. Modern methods of steel manufacture necessarily demand that the product be turned out in vast quantity and with rapidity, thus necessitating the use of materials such as manganese. Such methods cannot be overthrown at once, and we must look to the metallurgist for a solution of this problem. That such materials may assert a destructive action on the steel of which they form an integral part, there can be no doubt; the difference in potential of the area containing manganese in excess, to the potential of the area containing less manganese, causes the flow of an electrical current, with the consequent effect upon the solution of the metal. Marked segregation of the impurities is another factor of a destructive nature, and causes the formation of pit-holes which are of great danger.

Old vs. New
Methods in
Steel
Manufacture

Effect of
Manganese in
Steel

That these points should be given more careful consideration was made plain, very recently, on an inspection trip to the tunnels of the

Manhattan and Hudson Co. in Hoboken, New Jersey. Ten cars of one steel and ninety cars of another steel, that had been in service for six months, were brought into the roundhouse for examination. These cars had been built of two different grades of steel, but they were painted at the same time, with the same material and by the same workmen.

The conditions in the tunnel where these cars had been operated were most trying. Constant seepage caused drippings of an extremely corrosive nature to be deposited upon the cars' surfaces, and an analysis of the drip showed the presence of 15% of chloride salts which caused rapid acceleration of rust. The tunnel drip also had a solvent action on the paint coat and in several spots the drip had completely removed the paint. The atmosphere in the tunnel was rich in carbon dioxide and high in moisture containing a considerable quantity of salt.

The large amount of rust formed on the edges of the cars could be accounted for by the abrasion of road-bed dust, hurled against these vulnerable parts by the enormous pressure, and consequent blast, of air that is exerted when the cars are running at full speed in the tubes. Another condition observed was the appearance of a white coating of salt upon the surface of the paint after the cars had been in operation but a short time.

Subjected to these trying conditions, some of the cars stood the test in a remarkable manner, while other cars, made of a different grade of steel, were in very bad condition.

The points of corrosion were indicated by the surface being covered with wart-like concretions which, under a high power hand glass, showed the presence of rust forcing through the paint coat and exposing the steel to direct contact with the air. This eczema of the iron, although general, seemed to be most marked in certain places, and this would lead to the conclusion that the impurities in the metal were segregated.

According to the electrolytic theory of corrosion, certain fundamental principles underlie the corrosion of iron.

They are, briefly, as follows:

That, when iron is in contact with water, there will be a transfer of electricity from the free hydrogen ions of the water to the iron ions of the iron, causing the solution and subsequent oxidation of the metal.

The presence of impurities having a difference in potential to that of the iron in which they are contained, and the uneven distribution of such impurities, increases the amount of electrical action.

We are indebted to Dr. William H. Walker for the most recent research on the function of oxygen in the corrosion of iron, who says,

"That the film of hydrogen deposited on the metallic iron at the beginning of the action is a non-conductor of electricity and prevents further passage of the current, and hence, further solution of the iron. Atmospheric

Relative
Corrosion of
Two Grades
of Steel Under
Severe
Conditions

Appearance
of Surface of
Cars after
Service

Electrolytic
Theory of
Corrosion

"oxygen removes the film of hydrogen by combining with
 "it, thus 'depolarizing' the iron and allowing the solution
 "of the iron to proceed. When once in solution in water,
 "this dissolved iron is also oxidized by the atmospheric
 "oxygen and precipitated as rust; but this oxidation is in-
 "cidental to, rather than a necessary condition of, corrosion.

"That when iron is in contact with any surface on which
 "this combination of the hydrogen, set free from the water,
 "and oxygen, from the air, will take place more easily than
 "on the iron itself, such as copper, bronze, mill-scale, etc.,
 "corrosion of the iron will be accelerated thereby."

Certain compounds are of such a nature as to excite electrical action, and, consequently, stimulate corrosion, while still other compounds are of such a nature as to inhibit or prevent corrosion.

To the class of compounds that inhibit corrosion belong bichromates of the alkaline earth metals, these salts being pre-eminent among such compounds. It has been found that salts of certain metals may be precipitated with the chrome salts to produce pigments which afford protection for the steel surfaces to which they are applied.

The results of a series of investigations into the rust preventive nature of these compounds demonstrated that it was not safe to state that the chromates, as a class, were rust-inhibitives. Quite the reverse is true of many of these products, and their composition, method of preparation, and impurities are factors which influence, to a marked degree, their value as protective compounds. Aside from those chromates which prevent corrosion, we have those which act in an inert manner, also those in which any inhibitive value is overbalanced by the effect of impurities, showing a strong stimulating action in the rusting of metal. But a simple test will show in which class the chromates come.

Value of
Chromatic
Pigments as
Rust
Inhibitors

Turning, therefore, to the conservation of structural iron and steel and to its rust inhibition through particular coatings, we have the problem of choosing the proper materials for manufacturing a paint which will both exclude the agencies of rusting, and which, when moisture and gases do penetrate the coating, will inhibit the iron from rusting; and we also have the problem of giving to the chemist, engineer and architect some simple method of determining whether any given paint is, in at least a rough measure, harmful, safe or beneficial.

Preservation
of Steel and
Iron

Some pigments largely used in the paint industry, and of value in a paint for protecting lumber, are unjustifiable in a paint for the protection of steel and iron. For example, sulphate of calcium, which, even if fully hydrated, has been shown to have a direct stimulative action upon steel. This is due to the fact that calcium sulphate, even if fully hydrated, is somewhat soluble in water, and when the water penetrates the coating of paint it carries this calcium sulphate into solution. Owing to the fact that calcium sulphate, in solution, has a high co-efficient of dissociation (or, in other words, has a

Caution
Regarding
Pigments that
Corrode Steel

Caution
Regarding
Calcium Sul-
phate

tendency, in solution, to break up from its chemical form and identity), we get the reaction of the liberated sulphuric acid ions upon iron and steel, causing corrosion.

The highest types of paint product for the protection of iron and steel, therefore, avoids the use of such pigments as calcium sulphate.

Great caution must be used in selecting iron oxides for the protection of iron and steel, as they often carry traces of sulphates, etc., as impurities.

Caution
Regarding
Venetian Red

Venetian red, which is a favorite pigment, and which is of value for protecting lumber, is made by calcining green vitriol or sulphate of iron (commonly called copperas) in the ferrous form, in the presence of quick lime. The resulting mass from the furnace consists of artificial oxide of iron and sulphate of calcium, produced by the metathesis of the above reacting compounds.

Unfortunately, the reaction is never complete, and there is a tendency towards the formation of free sulphuric acid.

As a result, we have all the bad effects with Venetian red that we find in the use of calcium sulphate, and also the extra chance of corrosion due to free and aggressive sulphuric acid present.

Caution
Regarding
Artificial
Oxides of Iron

It is true that there are some *artificial* oxides of iron which can with safety be used, as for instance, artificial black magnetic oxide produced by chemical precipitation, but, as a general proposition, the *natural* iron oxides should be used, unless it is absolutely certain that the artificial oxide has been proven safe.

Ochres

Ochres are not meant to be included in the safe class in the above statements, for the reason that ochre is an extremely impure oxide of iron.

Groupings of
Pigments Into
Inhibitors,
Inerts and
Stimulators

Recent investigations into the nature of pigments have revealed the fact that they may be divided into three groups and termed "Rust-Inhibitives," "Inerts," or "Rust-Stimulators." The nature of the pigment itself, or the nature of the impurities contained within the pigment, are factors deciding the position of the pigment in one of the three groups or types above mentioned. It may be expected that the use of rust-inhibitive pigments in paints designed for the protection of steel surfaces will give to such a paint very valuable properties. Further consideration of the subject will aid us in selecting the proper pigments for such a purpose.

Steel Test
Fence

In order to ascertain the rust-inhibitive value of all pigments, the Scientific Section was commissioned by the Bureau of Promotion and Development of the Paint Manufacturers' Association to erect a fence, having several hundred steel plates, upon which to try out the value of the different pigments when contained in an oil medium.

The American Society for Testing Materials was informed of the work proposed by the Scientific Section, and Committees E and U of that society decided to cooperate in inspecting and supervising the tests, proper specifications to be drawn up by the committees. The members of these committees and the Scientific Section conducted laboratory tests that served as a check upon the previous investigations and gave information upon which to base the main field tests.

The plates used for the tests were rolled from three kinds of metal—ordinary open-hearth structural steel, ordinary Bessemer low carbon steel, and pure ingot iron. In this way was secured data relating to the resistance to corrosion of certain metals when tested out simultaneously with others. The steel plates were painted in two ways, part of them being scratch-brushed in the ordinary way before painting, thus following out the usual mode of painting structural steel, and part of the plates being pickled in sulphuric acid, in order to completely remove the scale, and the plates were subsequently washed with lime so that all traces of the acid were neutralized.

The test was conducted in a thoroughly systematic and practical manner, following out the methods employed during the tests already made at Atlantic City and Pittsburg. The Master Painters' Association co-operated in the work and gave us the benefit of their practical experience in this line. Inspectors and painters, representing the committees and sections, were upon the ground throughout the period during which these tests were made.

It has been proven that corrosion generally takes place under normal conditions in an uneven manner, and pitting is evident at certain weak spots on nearly every grade of steel or iron, in a lesser or greater degree. From these spots the corrosion proceeds and develops upon the surrounding area. The corrosion at the start, where the pitting begins, is so extreme in some cases that holes are formed, of considerable depth, before the surrounding surface is attacked to any marked extent. The causes of this pitting have been fully explained by the electrolytic theory. This theory overthrows the former theories which were held, regarding corrosion. The carbonic acid theory, for instance, held by Calvert, supposed that carbonic acid attacked the iron, converting it into carbonate, and the carbonate being oxydized to hydrate or ordinary rust by the oxygen of the air, the carbonic acid regenerated and acting again on an unattacked part of the metal. According to the peroxide theory, the iron, oxygen and water were supposed to react to form ferric oxide, and to regenerate hydrogen peroxide which would attack a new quantity of iron. That the electrolytic theory is the most tenable has been demonstrated in many ways, but one of the most beautiful demonstrations may be carried out in a very simple manner.

Pitting of Steel
and Causes

Different
Theories of
Corrosion

A five per cent. solution of gelatine in hot water is made, and, after careful neutralization, a few drops of phenolphthalein and ferrocyanide of potassium are added. A thin layer of this solution is poured upon the bottom of a glass dish, and when stiffened up by cooling, a clean strip of metal is placed thereon. A further quantity of the gelatine solution is poured upon the metal and allowed to solidify. The gelatine in this case is used to retard diffusion of the colorations which form. As stated before, when a strip of steel is placed in water, there are developed hydroxyl (OH) ions at the negative pole, and these are shown by a pink coloration formed with the phenolphthalein, whereas at the positive pole of the iron plate the development of hydrogen ions takes place, and solution of the iron

Electrolytic
Theory and
Evidence of
Its Existence

proceeds. This solution forms, with potassium ferrocyanide, a blue coloration which to the paint chemist is known as Prussian blue.

It is a well known fact that zinc protects the iron from corrosion when in contact, the zinc going into solution, being electro-negative to iron, thus protecting the iron from being acted upon. It has been found that the zinc will protect the iron only to a certain extent, unless an electrolyte is contained within the water, this being due to the fact that pure water offers too great a resistance for the current to flow.

It has been shown by our investigations that certain pigments have the property of preventing galvanic action, and their use is highly desirable in a paint coating. Other pigments have been found to exhibit a strong tendency to excite galvanic action because they possess the property of being good conductors of electricity. Such pigments should never be used next to steel.

The Scientific Section of the Paint Manufacturers' Association have made a very careful and systematic study of this vital question and are at present pursuing the work started, making tests of extreme value and recording their observations for future generalization. Such work can only be productive of the most valuable results and will ultimately result in the restriction to certain materials for use in painting iron and steel and the adoption of these materials in specifications for such work. The qualification of each and every raw product will be determined, and its legitimacy for existence in a paint will be closely questioned before giving it final approval.

It is not the intention to make any derogatory reference to certain products which are under suspicion or to attempt to tear down the business that has been built upon these products, but before we can give our candid endorsement to any raw product for use in a paint to be applied direct to iron or steel, that product must possess certain fundamental requisites which we have already outlined. The distinction between an inhibitive and a stimulative pigment may be easily determined, and it is essential to the preservation of the steel upon which such pigments are to be used, that the inhibitive principles should predominate.

That there is a marked difference in paints as well as in steel has been proven beyond the shadow of a doubt, and evidence is collected every day confirmatory to this statement. One of our foremost metallurgists recently returned from a visit to the Isthmus of Panama, and, while there, he inspected some of the old steam engines used by the French government, in their futile attempt to join the Atlantic and the Pacific. These engines had lain in the morass and jungle for many years, subjected alternately to the torrid heat of day and the excessive humidity of night; rare conditions for active corrosion being always present. Some of the engines were nothing more or less than a flimsy network of holes, and the material had completely gone to waste (of the open-work variety), resembling the latest thing in summer hosiery. Other of the engines had been protected with certain paint coatings that had preserved the

Protective
Effect of Zinc
on Iron

Grouping of
Pigments Into
Classes

Work on this
Subject Long
Pursued by
Scientific
Section

Corrosion in
Panama

Effect of
French Paint
Coatings

steel intact, and the American engineers were able to pull these engines out of the morass and by substituting a few accessories, to use them again. The nature of these coatings which have withstood the test of years are at present being investigated by the Scientific Section to determine the pigments used therein.

Another engineer recently returned from Colon reports that the iron posts surrounding the consul's home and from which were suspended a line of linked chain, showed active corrosion on the southeast side in every case, while the back of the posts were slightly, if at all, affected. These posts back of the consulate were unaffected in any place because of the protection from the southeast winds afforded by the house. The winds blowing in, laden with salty humidity, had naturally exerted their corrosive effect on the surface not thus protected.

Direction of
Corrosion
Effect of Trade
Winds on
Isthmus

A recent examination of the steel test fences erected by the Scientific Section, at Atlantic City, was confirmatory of the above. The inspection was made early one morning, after a rainy night. The weather had cleared up and the brisk wind which had continued throughout the storm was blowing from the same direction and rapidly drying the moisture on the steel plates. The object of the inspection was primarily to determine the moisture penetration and water shedding properties of each pigment and paint. A better day or time for such a test could not have been chosen.

Effect of Storm
Direction of
our Coast

As has been described before, the fences are three in number, made of three classes of steel and each presenting toward the sea a series of 100 plates with as many upon the reverse side. It was apparent at once that the rain had impacted only against the steel plates facing the ocean or shore side, and that our inspection would have to be made from the plates on the reverse side of the fence.

The panels facing the ocean and exposed to the action of the storm exhibited a variance of results. Some had been painted with pigments having a greasy nature, and being natural water-shedders were apparently dry, while others, painted with less greasy pigments, held on their surface a large number of rain drops. By wiping off these rain drops, the following differences were noted:

(1) That in some cases a place resembling a water blister was left, showing just where the drops had remained on the surface, and showing that they were acting upon the paint coat.

(2) In other cases, when the drops of water had been wiped off, the surface was in the same condition as the balance of the plate, and the rain had no apparent effect upon the paint coat. On some panels, the penetration of moisture through the paint coat left a blotchy surface. This appearance being present on many panels, a record of impenetrability was obtained.

Inspection
Steel Fence
in Atlantic
City to de-
termine Impe-
trability
and Water
Shedding
Properties

Very few corporations, whether manufacturing paints or buying paints, and very few engineers or architects have the facilities or the time to make exhaustive laboratory research when choice is to be made of a protective coating for their use.

What the practical man—either the paint manufacturer, the archi-

tect, or engineer—requires, is to have some practical result, easily obtainable, which will give him, in a definite and visible manner, a criterion and measure of the value of the new discovery, and of the refined laboratory work.

This accelerated field test consists in subjecting strips of any particular kind of steel that may be chosen to an atmosphere of maximum humidity, the steel being in intimate contact with the materials concerning which results are desired.

The apparatus is extremely simple, and the test can be started at thirty minutes notice by any manufacturer, architect or engineer, at his office desk, and can yield him visible results in two days thereafter.

The idea was original with Dr. Cushman, and permission was requested from him to work it up in some practical way for the manufacturers of the raw materials and of paints, and for the consumers who have the work of protecting structural steel.

The chemist, engineer or architect who wishes to conduct this test on actual paint products instead of the materials used in the manufacture of paint products, may use a \$7.50 centrifuge apparatus made by Bausch & Lomb, in other words, a small laboratory centrifugal machine holding test tubes.

Number the test tubes for reference purposes and place in each test tube a small sample of the paint to be tested, together with a large quantity of benzine. It is of extreme importance to add the benzine in considerable quantity and previous to inserting the tubes in the centrifugal machine.

Actuate the apparatus and most of the vehicle will be thrown away from the pigment and the pigment will settle toward the bottom of the tube.

Decant or pour off the oil, add more benzine, thoroughly shake and pour off the liquid. Do this two or three times until the oil has entirely left the paint and nothing remains but the dry clean pigments.

Then take the pigments and proceed with the whole test as described below for the testing of dry pigments.

The materials required are as follows:

An ordinary deep cigar box.

2 or 3 sheets druggists' thick filter paper.

1 dozen thumb tacks.

1 dozen safety razor blades (unless some special steel is to be tested).

½ dozen small butter dishes or saucers.

Each of the dry materials to be tested.

A clean pencil for stirring.

A pocket knife.

A glass of water.

An old towel or rag for cleansing hands, pencil, etc.

A piece of emery cloth.

A tooth brush.

2 or 3 test tubes.

Line all six interior surfaces of the cigar box with the filtering paper, using the thumb tacks for the purpose. Thoroughly wet the lining of the cigar box with water and stand it on one edge so that when it is ready for use it will be free from drip.

Sweat Box for
Testing
Pigments on
Steel

Place upon a piece of filter paper, large enough to cover the hand, some of the material under examination, add a few drops of water and rub up with the finger into a rough soft paste, this being easily accomplished with nearly all pigments, and bringing into a paste many pigments which are otherwise extremely difficult to incorporate with water. Be particular to cut the surface of the razor blade to the raw steel with "oo" emery paper, to insure the removal of any lacquer or surface treatment of the blade. It is necessary to handle the razor blades by the edges so as not to get any finger marks upon the surface. Now place a clean razor blade upon the plate, fold over the filter paper on each side of the razor blade in such a manner as to completely cover it with paste-coated filter paper, and place blade, paste and paper upon a butter dish within the cigar box.

Treat each sample of material under test in the same manner.

A word of caution is necessary regarding the testing of the inhibitives such as the chrome soaps, that are soluble in linseed oil.

These are not pigments, but soluble in the oil and vehicle constituents, and therefore must not be applied in a water paste, but in a film, through the agency of benzol.

In the case of these materials, soluble in linseed oil, such as resins and linoleates, these are to be dissolved to a heavy solution in benzol, and a coating poured upon the razor blade. The evaporation of the benzol leaves upon the surface of the blade a thin film of the material to be tested, and, because of the fluidity of the benzol and consequent thinness of the film, a second coating is advisable. The coated blade is then to be placed in a butter dish within the box along with the other materials with which it is to be compared. Care should be taken that the plate is completely coated as there is a tendency for the liquid to segregate on the steel.

Caution
Regarding the
Testing of Ve-
hicle Soluble
Pigments

If a strip of steel in every case be treated with potassium bichromate in such a test, a convenient standard of minimum corrosion will be afforded, for purposes of comparison.

Standard
Tests

If so desired, in the foregoing test the operator may increase the quickness with which the test may be performed, by adding to a little bicarbonate of soda (baking soda) on a butter dish, a little sulphuric acid. An evolution of carbonic acid gas will ensue and as this gas rapidly stimulates corrosion, its presence will render the test still more positive.

A considerable degree of refinement and a fair index of result can be obtained from this apparatus if the strips are first carefully weighed in a laboratory balance, and then reweighed after the steel is scrubbed with a tooth or nail brush to remove any rust formed, in which case the loss in weight of the steel is the measure of the rust formed and the degree to which the pigment has stimulated rust.

Quantative
Test with
Sweat Box

It is evident to any man who will compare the conditions in this

test with the field conditions, that practically all of the important factors which contribute to the corrosion of steel are present in this test in such a way that they will indicate in a short time the results which would be obtained from the steel painted with a paint coating produced from these materials and over a considerable length of time.

Addition of
Resin to
Render Vehicle
More
Water Repel-
lant

After the proper selection of pigments has been made, the question of vehicle must be carefully considered. The addition of high grade fossil resins, carefully compounded with a carefully treated oil, adds greatly to the power of a paint to resist penetration by gases and moisture, producing a better excluding paint and at the same time adding to the appearance. The glossy surface which a paint made along these lines possesses renders the paint a better repellent or resister of moisture. The quality and percentage of gum used influences to a great extent the wearing properties of this kind of paint.

Effect of Oil
Shop Coat for
Steel During
Transporta-
tion

During the transportation of machinery and structural steel from the factory to the field and the workshop, there is met a state of conditions that causes rapid corrosion. Moisture and gases attack the metal and assert their destructive action. In the past these results have been partially overcome by swabbing the metal with crude oil, in some cases, and, again, by giving the metal a dip in hot linseed or other drying oils or by applying tar and cheap paints as shop coats. The crude oil leaves upon the surface of the metal, even after wiping, a quantity of non-drying mineral oil which interferes with the drying of the paint coat which is afterward applied at the time of the assembling of the metal. It also prevents the paint coat from properly adhering to the steel surface, and this coat of crude non-drying oil, which still exists between the metal and the paint coat, is a source of never-ending trouble, causing peeling and shriveling. This crude oil treatment, therefore, should be avoided whenever it is intended that the steel is to be subsequently painted with oil paints.

Appliability of
Transparent
Shop Coat
made
Inhibitive

Where linseed oil instead of crude oil is used, a film of the oil is left upon the metal and rapidly oxidizes to a coat of linnoxyn. This coat will protect the metal for a certain period of time, but is extremely porous and ultimately admits moisture. If, within this coating of linseed oil, there had been contained a proportion of pigment, or if the linseed oil had been developed by gums into a varnish or lacquer, then the excluding properties of the linseed oil would have been increased, and, if the formula were inhibitive in nature, the steel would be better protected from corrosion, and the application of future coats of paint, after assembling the steel, would have been practical and facilitated.

It is sometimes desired to give to steel a thin adherent protective coating that is transparent and will allow of the inspection of the steel by the engineer, who desires to observe whether the metal is absolutely clean and free from rust before proceeding with the painting thereof. In a case like this, there is required a coating of oil containing materials which will not interfere with the transparency of the oil coat and which, at the same time, are thoroughly inhibitive

in nature. Such a compound may be prepared by the use of inhibitive chromium compounds soluble in linseed oil, such as chromium resinate or chromium linoleate. By the use of these materials within an oil coat, thorough inhibition is obtained, and, at the same time, there is added the excluding properties which these compounds afford. A thoroughly inhibitive and transparent coating is thus formed and is most practical of use. A paint coat applied to steel protected by this inhibitive oil coat amalgamates with this oil coat and becomes an integral part thereof, rendering at the same time, the oil paint thoroughly inhibitive and causing close adherence to the metal surface.

DISCUSSION.

Mr. George M. Davidson, M.W.S.E.: I would ask Mr. Perry what he thinks of lamp black as a protective coating?

Mr. Perry: Thus far we have found lamp black in the same class as graphite, carbon black, etc. You will remember, gentlemen, that I said those materials are the most wonderful excluders we have,—the most noted in their characteristics of exclusion, and give high excluding values to a paint. Unfortunately, however, when the paint coatings begin to give way the evil starts. There are some blacks which are safe—blacks made from vegetable and animal charcoal, containing small percentages of alkali, which are slightly inhibitive—and they can be used as substitutes for graphite, carbon black, etc. Please understand, though, that I am not attacking lamp black, graphite, and carbon black; I am simply trying to state exact facts from a technical standpoint, and any of you can determine these facts for yourselves.

Mr. Davidson: I have an example in my office, showing the durability of lamp black on iron, in the way of a piece of 3 in. suction pipe taken from a well. When that piece of pipe was sent to the point where the well had been dug, it was marked with the initials of the railway company, in lamp black. That pipe was eaten through by corrosion in a great many places, and has the appearance of having had a good case of smallpox, except where the initials of the railway company were put on. In that case it would seem that lamp black offered a protection to the material from which the pipe was made.

Mr. Perry: I am very glad that Mr. Davidson brought up this illustration. I could not have asked for a better one, to show exactly what happens when those blacks are used with iron and steel. I am going to use a homely example, for instance, a wet battery such as is used in operating telegraph instruments. It is composed of carbon, zinc, and solution; by wire connection you get an electric current. The zinc dissolves in proportion to the electric current, while the carbon remains unaltered for any length of time it is left there. If iron is substituted for that zinc you will get an electric current and the iron will dissolve in that small glass battery in proportion to the electric current, but the carbon will remain undissolved for any length of time. When the lettering was put on the pipe which Mr.

Davidson has referred to, and the pipe was plunged into the water, it made a very nice battery. The iron dissolved and the carbon remained intact—a beautiful proof of the fact that carbon is a poison to iron.

Mr. E. N. Layfield, M.W.S.E.: The use of the test in determining the two values of the pigment, was not very clear to me. One of the values of the pigment is its inhibitive value, and the other is its excluding value in a paint. This test, as I understand it, showed only the inhibitive value and not the excluding value. We will suppose we had a pigment comparatively low in inhibiteness and very high in exclusion; what would be the result?

Mr. Perry: You have put your finger right on the matter. The first thing to be done is to set aside all those compounds which are poor excluders and forget them; then from among those which are good excluders choose the ones which are good inhibitors or which are inert, but not those which are rust-stimulatives. I stand corrected, that to-night I did not take up the question of the function of the pigments as excluders, because it would have made my paper too long, but I have handled that phase of the question fully in other lectures. It is largely a "rule of thumb" matter and the result of years of experience of paint manufacturers. Fortunately some of the best excluders are rust resisters.

Mr. O. P. Chamberlain, M.W.S.E.: I presume, Mr. Perry, the idea is to take out the pigments which you know are excluders, first, and then make a test of them.

Mr. Perry: Yes, that is the idea.

Mr. Charles K. Mohler, M.W.S.E.: While I understand that Mr. Perry has studied the question almost entirely from the standpoint of paint protectives, I would like to know if he has made any study at all of the action of concrete and mortar in excluding rust? This has become a very important factor in building construction, and I would like to know whether it is a protector and can it be relied on.

Mr. H. A. Gardner: The protective properties that concrete or cement sometimes afford structural steel is due to the percentage of lime they contain, the lime acting as an alkali prevents the formation of hydrogen ions which is one of the primary causes of corrosion. Nevertheless when steel or iron beams are embedded in concrete and they are connected by metal, there will sometimes be a flow of electric current unless the metal is thoroughly insulated. Consequent corrosion generally forms at the beam which is the anode and the corrosion proceeds, in some cases, to a great extent. The molecular increase which takes place under these conditions is very apt to cause a splitting of the concrete. It is thus evident that even in the presence of a large percentage of lime, cement is not a protective against electrolytic corrosion unless there is absolute insulation of the steel and iron.

Mr. F. H. Bainbridge, M.W.S.E.: I would ask if there is any good reason why the rail which is in use is generally free from rust, while the rail which is out of use rusts rapidly.

Mr. Perry: I will try to answer that question in part. The effect is partly deceptive. The rail in use is being constantly hammered, and if you will examine the right-of-way you will find discoloration on either side of the rail. In other words, the freedom from rust is deceptive in its appearance, as the rust is being constantly removed by the passing trains. That is part of the answer and a practical one. There is another question, however, which is rather involved and which is being followed out,—a theory that the actual use of the metal causes depolarization. That is a very large question and a very technical one.

Mr. Bainbridge: I know of some iron tanks in water service which have been in constant use for twenty years; they were not painted inside and there is almost no evidence of corrosion in those tanks at all. If the tanks had been left for six months without use, without question they would have gone to pieces very rapidly.

Mr. Gardner: Nearly the same thing happens in water carriers. The water flowing through the pipes does not allow foreign matter to be deposited, whereas if the water is allowed to stand in the pipes, impurities and foreign matter collect and act as electrolytes, stimulating the action of any electrical currents which may be present. As long as the water is kept in rapid motion, there is little opportunity for rusting to take place, even when the water contains a very small percentage of acid. I would like to ask Mr. Bainbridge whether the water in the tanks he mentioned was of alkaline reaction?

Mr. Bainbridge: The tanks I referred to were in use on the Santa Fe road, out at Belmont, Arizona. The water was good drinking and washing water.

Mr. J. H. Warder, M.W.S.E.: Some years ago, when at one of the eastern bridge shops, they had a contract that required the completed bridge members to receive a coating of some asphaltic mixture, put on hot. A wooden tank was built, long enough and large enough to take in the large, complete member, as an end post. Steam pipes in the bottom of the tank served to heat up the asphaltic mixture, and the bridge members were immersed therein until the metal was thoroughly heated through and then lifted out and the surplus coating drained off. This operation must have added considerably to the cost of the bridge, and from what has been said about bituminous paints, was this extra work a waste of money?

Mr. Perry: The asphalts are practically a poison to the iron and steel, and if careful observation had been made in those cases after two years, the corrosion would have been found under that coating. I will ask Mr. Gardner to describe certain tests where bitumen was used.

Mr. Gardner: The bitumen we used on plates was coated with red lead. After the plates had been on the fence for about a month, an observation was made and in nearly every case a fine checker-board work was to be found. The unequal expansion of the red lead and of the bitumen caused those cracks to be formed.

Mr. W. H. Finley, M.W.S.E.: A number of years ago some water pipes were being placed in the city of Minneapolis, and these were immersed in hot asphalt until the metal was brought to the same temperature as the asphalt. An examination some years afterward showed the pipes to be in an excellent state of preservation. Of course, that is very different from just painting.

Mr. Perry: I agree entirely. I will give my own practical experience as an engineer, and say that those tars, asphalts, and bitumens have been found dangerous unless lime was added and boiled with the tar or bituminous material. I think in England lime is always used.

Mr. Finley: In connection with railroad structures, probably one of the worst things to be dealt with in the matter of corrosion is the drip of brine on structures. I have seen the brine go through all sorts of protectives, the result being rapid rusting. I do not know yet of anything that has given good results in this matter.

Mr. Perry: Mr. Gardner was present at some inspections along the line of this brine question, and he will tell you something about that.

Mr. Gardner: Regarding the action of brine on steel and iron, I might state that the corrosion is very rapid. In sea water there is a large percentage of chlorides of sodium and magnesium, both salts which are easily dissociated into their component parts, the chlorine ions attacking the iron with great rapidity and accelerating corrosion to a great extent. These salts also act as electrolytes and increase the conductivity of water, promoting galvanic action.

Mr. Perry: I might add that the scientific paint coating to protect steel is first impenetrable, and second, when with age it becomes penetrable, it will be inhibitive, and you must understand that it is not a perfect paint coating, but simply the best we have been able to produce as yet. The new science is very young—only about six months old—and less than two years old in its conception.

Mr. Finley: Is the paint that is made of the gum or resin flexible enough to take care of the expansion and contraction of the iron?

Mr. Perry: One should go to paint manufacturers of established reputation and experience and be willing to pay their price to get the safe percentages and the proper gums dissolved in that oil, or you will get an absolute failure in that you will get a varnish that will not stand exposure.

Mr. Warder: It will not do, then, to simply take a varnish and mix it in with your paint?

Mr. Perry: No, you are correct in that.

Mr. Finley: You spoke of using lacquer as a shop coating. Is it possible to apply that to the iron or steel in bridge shops? Do you get a good result in such a case?

Mr. Perry: The suggestion which I made to-night and which I have carried out in tests was the use of a very limited amount of those resinates, or compounds of chromium, not exceeding 5 per cent., of

those materials to form a sort of lacquer on the iron, with no thought of its permanence. It is safer to put on a material of that kind, rather than a cheap dope which will cover up the defects of the iron so the purchaser cannot see the quality of material he is getting.

Mr. Finley: Of course, all engineers know that linseed oil does not give protection for any great length of time. A few years ago it was customary to put a coating of linseed oil on iron to protect it previous to its use, but if any length of time elapsed before the iron was used the fact was disclosed that linseed oil did not offer any protection. The question in my mind is whether there is any particular advantage in using the lacquer over the oil.

Mr. Perry: I know the lacquer will give greater life and greater impenetrability during that life which is short. It is sufficient for any reasonable time until the job is ready for the material.

Mr. Finley: Would you recommend any particular paints for the first coat, and other kinds of paint for additional coats? Could you get any better results?

Mr. Perry: It has been suggested by Dr. Cushman that a strong inhibitive priming coat should be put upon the structural steel on a job, and then follow that with final coatings that are extremely good excluders. The Committee of Inspection, when at Atlantic City last month, were of the opinion that it would not be safe to recommend that until we have made exhaustive tests to determine whether the difference in elasticity would render it unsafe, etc., and whether the difference in constitution of the final coatings might not introduce a danger. There would be a tendency for the material to create in themselves an electric tension, through which, in the presence of the moisture, considerable pitting would be created. We are going to make a series of tests on these very questions you have brought up.

Mr. Layfield: Is there any reason to suppose that the pigments which are the best inhibitives as shown by this test, would be the best in resisting locomotive gases?

Mr. Perry: In other words, you wish to know whether those materials which are known to create a passive condition of the iron—which inhibit corrosion or retard it—will do so in the presence of actual acid gases. They will, and I would like to have Mr. Gardner take that matter up for you. He will show you just why they will do so.

Mr. Gardner: If a plate of iron or steel is placed in a jar containing a dilute solution of potassium bichromate, there will be no corrosion taking place. If to this solution of bichromate is added a weak acid in small percentage, the stimulating effect of the acid will be overcome by the inhibiting effect of the bichromate.

Mr. Layfield: Mr. Finley's remarks have reminded me of another point. Is the zinc chromate as good an excluder as the graphite?

Mr. Perry: In answer to that question I will say no. I am glad that point was brought up, because some paint manufacturers, without

a proper knowledge of the subject, have the idea that because zinc chromate is good in a small percentage, it will therefore be good to make a paint out of it entirely. We do not say it is a bad thing, but we deal only in what is good, and we do not recommend it. $2\frac{1}{2}\%$ to 5% of the zinc chromate will give the desired inhibitive values. Anybody can put it in paint if it is specified.

Mr. Warder: Suppose you have a supply of paint of which you are a little suspicious. Can you make use of that paint by adding to it some of this zinc chromate?

Mr. Perry: If you are suspicious of a paint I would suggest that you give it to your colored man.

Mr. Layfield: By putting zinc chromate in graphite, would it make the graphite more inhibitive?

Mr. Perry: You might stimulate the effect of the graphite and create deep pitting.

There is this to be said about graphite paints. While we know they are sometimes extremely poisonous, we often find the steel in very good condition after the graphite has been on for a long time. We know they are good excluders and water shedders.

It may interest you to know that the American Metal Workers' Association at their Buffalo meeting passed a resolution, through their committee on protective coatings, which was unanimously adopted, warning their members against using the graphites and blacks on metal. That is a matter of record, and it is also quoted in the scientific bulletins. The men who are advertising graphite do not advertise this fact, but those metal workers represent practically a "rule of thumb" method of experience from one ocean to the other.

Mr. Bainbridge: Do not some of the graphite manufacturers put zinc chromate in their product to make the color green?

Mr. Perry: Zinc chromate is quite expensive, and has never been used for any such purpose, because the graphite manufacturers are making the cheapest paints on the market. They use greens, but they are the greens that chemists use, not the zinc chromates. A very small percentage of the latter costs perhaps 8 cents per gallon of paint which is expensive.

Mr. Bainbridge: I have here a sample of iron which was put into the Missouri river in 1863 and was exposed to the current all those years—45 years. On this side, where it was against the crib, it was never painted. The other side was painted with one coat of red lead. The iron had been out of the water two or three days before I saw it, but there was quite a bright coat of red lead on it. The other side was not rusted so very badly.

Mr. Finley: Before that was put in the crib it was used on the Chicago Union Railway as a strap rail, so it had been subjected to considerable use in the way of having railroad trains running over it before it was placed in the crib.

Mr. Gardner: That was probably the Swedish charcoal iron which I spoke of as being used in the manufacture of wire fences twenty years ago.

Mr. Bainbridge: No, it was not charcoal iron; it was rolled in Buffalo.

Mr. Finley: That iron was rolled in the days when they made good wrought iron.

A statement in the first part of this paper to the effect that rusting is due to inferior material in the iron, or the lack of coating with zinc, brought to my mind something I saw in one of the magazines that on the Isthmus of Panama the galvanized iron sent there by the French was still in a good state of preservation, while the galvanized iron and steel sent there by the United States rusted within six months. Is that due to the material or the coating?

Mr. Perry: It is due unquestionably to the material and the coating. Take two wire fences, each of exactly the same metal—one well coated and the other poorly coated with the zinc. You will get greater corrosion and more rapid destruction of the fence poorly coated. The coating is, however, not so marked a factor in the rapid destruction of the wire fences to-day as the poor metal used in making those fences. In these days, under the great stress of competition, manufacturers have made use of extremely unsatisfactory metal in turning out the great tonnage of these woven wire fences.

Mr. Finley: I can imagine that poor coating is made use of also.

Mr. Perry: Yes, the same men who furnish the poor metal are apt to put on a poor coating. In some parts of the West the wire lasts only three years. On the other hand I examined a fence recently in Georgia which was bought and erected by Hamilton Yancey shortly after the war. His grandson has removed it to another part of the plantation, and it is to-day in an excellent state of preservation. Some of the fence was galvanized and some was not.

Mr. Finley: Was the ungalvanized fence unpainted?

Mr. Perry: It was unpainted.

Mr. Finley: What we need is good iron rather than paint.

Mr. Perry: If you had good steel many of your problems would disappear.

Mr. Finley: I should think that the poorer the steel the better the coating that would be necessary.

Mr. Perry: There are extensive tests going on at Pittsburg, which are primarily under the direction of the Department of Agriculture, and we, together with the steel companies, are collaborating in that work. The tests are in connection with woven wire, and we are testing out these problems.

Mr. Chamberlain: What Mr. Perry has said with reference to some structures which were painted with graphite paint being found to be in extremely good condition reminds me of a little experience which came to my notice a number of years ago. Some practical tests were attempted on a railroad with which I was connected at that time, in the way of painting steel plates or wrought iron plates—with different paints and subjecting them to the practical tests of receiving the fumes from the locomotives in train sheds and *through*

bridges. The plates were hung up on some of the bridges along the road, and also in a large train shed and examined from time to time. While I had no direct supervision of the work, I remember the test very well. One of the paints that was considered good in its protection of the steel was graphite, and another was one that was called a rubber paint. These two paints were among the paints most severely condemned by the chemist of the road. It seems to me the practical tests in graphite paint or any other paint ought to, in a measure, confirm the diagnosis of the chemist in the matter.

I do not think Mr. Perry explained why, in some cases, the graphite paint did seem to take well and in other cases it did not; in other words, it aided in the corrosion.

Mr. Perry: If, as between two tests, in one the graphite shows protection and in the other the graphite has failed, we still are not certain that the metal is a constant in its quality. Or, to reverse the matter, if the metal is a constant, we are not certain that with two graphites you will get different results. The trouble has been that too little attention has been paid to this subject in getting absolutely uniform conditions under which to make these tests, so you can be sure of your conclusions. The whole art of the paint manufacturers was a "rule of thumb" method, and it is only within recent years, when structural iron and steel means the investment of immense sums of money and the reputation of those in charge of that work, that we are addressing ourselves properly to this problem of discovering the conditions under which the tests are made, so we can draw safe conclusions. Thus far, where all conditions of the tests are known, the graphite has not given good results.

Mr. Houston Lowe (Dayton, Ohio): The electrolytic theory of corrosion is interesting and plausible; however, the fact that electrical attraction and chemical affinity are one and the same may be at times disregarded. My own thought is that the inhibitive action of zinc chromate is due to the fact that it is slightly soluble in water, and as the essential property of paint pigment is insolubility, Mr. Perry's advice, that it be used sparingly, should be followed. The commercial varieties of zinc chromate may contain small amounts of impurities, which may cause it to stimulate rather than prevent corrosion. Its quality is dependent upon the material from which it is made and the method of manufacture.

I do not agree with Mr. Perry in his statement that as a general proposition the natural iron oxides should be used for protective coatings, unless he will qualify his words to mean natural ores roasted.

Mr. Perry: I want to agree with you on that.

Mr. Lowe: In regard to Mr. Finley's remarks about salt water drip: Although this is undoubtedly a more active agent of corrosion than fresh water, yet it has been my experience that salt water has less effect upon dried paint than has rain water. It is the mechanical abrasion due to the drip from refrigerator cars that injures the

paint coating, and its disintegration is further due to the action of the water lodging and evaporating upon its surface. So soon as the continuity or the integrity of the coating is destroyed, the corrosion of the exposed metal is rapid. Railway companies could save money by frequently touching up those portions of steel structures that are subjected to special injury of this kind.

Graphite paints of certain kinds have at times given excellent results in protecting steel, therefore it seems possible that the action of the American Metal Workers' Association in warning its members against the use of carbon paints on metal was somewhat hasty. It may be well to recite to you my conception of the factors that affect results in painting, namely:

1. The location of the structure.
2. The kind and condition of the surface over which the covering is spread.
3. The weather conditions when painting is done.
4. The quality and temperature of the paint.
5. The workmanship of the painters.
6. The number of coats applied and their sequence.
7. The time allowed to elapse between coats.

Neither the manufacturer, the architect nor the engineer can confidently predict results without knowing each of these things.

Mr. Finley: Would you say the more coats the better?

Mr. Lowe: Yes, generally, up to five coats. Linseed oil does not reach its most stable condition under several weeks after it has been applied. Dried linseed oil gets better and better up to a certain stage, and then it begins to deteriorate.

Mr. Perry: I want to thank Mr. Lowe for what he has said. He is a man has spent a life time in this work and knows whereof he speaks. I want to endorse Mr. Lowe's statement in the matter of graphites, and that there are many other things or conditions than the paint also to be taken into consideration, and one must be sure that these conditions are exactly uniform.

Mr. Layfield: I got the impression from what Mr. Lowe said about the oil improving for several weeks, or even months, after it was applied, that he might mean that that time should elapse between coats.

Mr. Lowe: I do not know, but I believe that if you can allow a month between the application of the different coats of paint on a bridge, you will get much better results than you are now generally getting.

I may speak of steel underground pipe. While the relation of carbon to iron is undoubtedly an established one, yet my experience has been that if an underground pipe coating is made from gilsonite and linseed oil, it will prolong the life of the pipe many years. I

think Prof. Sabin will give similar testimony. The result depends largely upon the temperature and the conditions under which the material is applied. It should be applied rather hot, and the temperature of the metal should be about that of the liquid, otherwise air bubbles will be produced. Then my experience is, too, that it is better to bake it at a moderate temperature, after it is removed from its bath.

Mr. Perry: I would like to add, in connection with Mr. Lowe's remarks, that I heartily recommend gilsonite under these conditions.

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BUREAU OF PROMOTION AND DEVELOPMENT PAINT MANUFACTURERS' ASSOCIATION OF THE UNITED STATES

Bulletin
Number

- Preliminary Booklet—Addresses on Paint, Delivered Before the Michigan Chapter, American Institute of Architects, 1907.
- 1—Tables of White Pigments and Vehicle—Standard Nomenclature.
 - 2—Standard Can Sizes Recommended to Paint Manufacturers.
 - 3—First Report on the Test Fences Erected by the Scientific Section. (Out of print.)
 - 4—Methods for the Analysis of the Vehicle Constituents of Paint.
 - 5—Tests Upon the Corrosion of Iron to be Conducted by the Scientific Section. (Out of print.)
 - 6—First Annual Report of the Scientific Section.
 - 7—Preliminary Report on Steel Test Fences.
 - 8—Report of Committee "E" on Preservative Coatings for Iron and Steel.
 - 9—Recent Technical Developments in Paint Manufacture.
 - 10—Protective Coatings for Conservation of Structural Material.
 - 11—The Corrosion of Iron and Steel. By Albert Sang. (Out of print.)
 - 12—The Function of Oxygen in the Corrosion of Metals. By William H. Walker.
 - 13—Protective Coatings for Steel and Iron. By Robert S. Perry. (Out of print.)
 - 14—Coatings for the Conservation of Structural Material.
 - 15—Protective Coatings for Structural Material. By R. S. Perry.
 - 16—Atlantic City Test Fence—Report on First Annual Inspection. (In press.)
 - 17—Pittsburg Test Fence—Report on First Annual Inspection. (In press.)

